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PUTTING KNOWLEDGE TO USE:
THE ACQUISITION AND TRANSFER
OF KNOWLEDGE IN SITUATED
PROBLEM SOLVING ENVIRONMENTS (U)

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approach to problem solving. Finally, applications of the research suggest new forms of intelligent tutoring systems.

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SUMMARY

Within cooperative learning great emphasis is placed on the benefits of "two heads being greater than one". Yet, research in cooperative learning has not placed emphasis upon naturalistic problems, metacognition, collective induction, and perceptual experience; and the influence such factors have on knowledge transfer. To be beneficial, cooperative learning problems must be ill-defined, have several competing solutions, and be situated in perceptual-based, real world contexts.

Experimental studies using the Jasper series (a laser-disc based experimental macrocontext) addressed these concerns and specifically investigated group-to-individual transfer in cooperative learning. The paradigm utilizes acquisition and transfer problems to examine whether unstructured cooperative/individual learning settings result in analogical transfer. The level of collective induction within the group was also examined as a factor influencing transfer. Literature on generational learning suggests that generating knowledge helps to access knowledge for future situations. Consequently, the hypothesis is that groups that share inductive activities, as opposed to groups which tend to be dominated by a strong individual, result in better transfer.

Results show that the Jasper macrocontext affords different types of activities for cooperative versus individual learning, which affect transfer of knowledge in different ways. Groups do better than individuals and pseudo-groups for total amount of problem elements solved for the acquisition task. Individuals do better on the total amount of problem elements transferred but groups do better than individuals on the more complex aspects of transfer. This was attributed to individuals spending more time exploring the macrocontext. Shared groups also showed some advantages over dominant groups for certain measures of transfer. A new criteria for determining dominance in a group, level of cognitive activity, was found to be a useful construct to replace more traditional measures.

Additional analyses suggest that above average groups perform better on certain measures, when compared to below average groups for transfer problems. Results also revealed differences in metacognition across learning settings. Metacognitive monitoring strategies are best for knowledge acquisition but solution elaboration strategies are best for

knowledge transfer. The discussion draws implications for cooperative learning and knowledge transfer as mediated by the roles of perceptual context, collective induction, quality of solution, and metacognition.

PREFACE

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CHAPTER I

INTRODUCTION

Currently, the field of Cooperative Learning (CL) is a burgeoning enterprise, important for researchers and practitioners alike, yet the question of what counts for success remains an open issue. Conventional wisdom has suggested that in some cases "too many cooks spoil the broth", while in others, "many hands make light work". These adages suggest that success or failure is inextricably tied to the situational context, conditions, processes, and measures which compose any given CL orchestration. The purpose of this proposal is to address these factors by proposing studies which clarify relationships between group process and individual learning. The objective is to assess how the group's process affects the subsequent learning effectiveness of its members. The nature of learning in groups will be observed from two perspectives: (a) the level of *collective induction*¹ experienced and (b) the type of *metacognitive/cognitive activities* employed. The paradigm used to test learning outcomes employs the use of a learning group which cooperatively solves an ill-defined naturalistic problem and then tests each member individually on a similar problem which is designed to assess transfer performance. This group-to-individual transfer outcome is then compared with pseudo-group and individual-to-individual transfer outcomes to properly evaluate the effectiveness of CL. This analysis is predicated upon addressing practical, methodological, and theoretical issues preeminent in the field of CL today.

Practically, an emphasis on having people work in groups has increased considerably

¹ Collective induction is defined as the ability of the group to generate ideas, knowledge, and hypothesis formation/evaluation beyond which one person could induct alone.

during the past 5 to 10 years. In many cases, the basis for success in CL suggests that when students cooperate as a group, many positive benefits can often accrue (e.g., Dansereau, 1988; Fletcher, 1985; Gabbert, Johnson, & Johnson, 1986; Johnson, Johnson, & Stanne, 1986; Slavin 1983; Webb, 1982). Success is often prevalent in research as well as educational settings. Many educators (Damon, 1984; Stodolsky, 1984; Webb, 1985) support and advocate CL in classrooms as well. Indeed, various models of cooperative learning are now in use (e.g., *Jigsaw II*, Slavin, 1980; *Co-op Co-op*- Kagan, 1985), and are applied in various areas such as engineering education (Smith, Johnson, & Johnson, 1981), English composition (Meeks, 1987), and home economics education (Way, 1985). In some instances, CL is being applied at the college level as well (Spear, 1988).

The underlying rationale of having people work in groups is that in some cases groups do no worse than individuals (with the added benefit that there are social advantages of members getting to know one another), but in most cases groups do better than individuals. This is reinforced by a variety of CL reviews (Johnson, Maruyama, Johnson, Nelson, & Skon, 1981; Johnson & Johnson, 1985; Johnson, Johnson, & Maruyama, 1983; Slavin, 1983). For example, Slavin (1983) found that out of 46 field studies 29 showed favorable CL effects, 15 showed no differences, and only 2 favored the control group. However, there is disagreement as to the underlying reasons accounting for success.

From a methodological perspective, there are problems in many studies which compare a group with an individual. Much of the confusion centers on the definition of assessment and measurement of learning outcomes within the context of group process. Even though learning invites a change in behavior over time, many studies cited to support the positive benefits associated with CL: (a) do not prescribe conditions designed to assess the nature of changes which occur across time and (b) do not make use of pseudo-groups to properly assess the synergistic aspects of group process. A majority of the studies already cited have defined the measurement of learning only in the context of what the

group does on a single acquisition problem and fail to evaluate in terms of how the group affords transfer of learning for future endeavors. Just because a group does well does not mean that all members of the group will do as well in the future.

In spite of these methodological shortcomings, the various CL techniques and studies indeed indicate that CL is growing and is an important form of applied research. Yet, from a theoretical perspective the apparent positive benefits and success of the field must be viewed with a healthy criticism. Dansereau (1988) indicates that CL research lacks sufficient controls, as well as fails to use current theories associated with cognitive approaches to learning. Slavin (1987) believes that research on CL has developed so rapidly that it may have outrun its theoretical underpinnings. As a consequence, there are a wide range of results that suggest different contingencies for determining when cooperation results in success or failure.

Recent studies (Gabbert, Johnson, & Johnson, 1986; Dansereau, 1988; Hythecker, Dansereau, & Rocklin, 1988; Larson, Dansereau, O'Donnell, Hythecker, Lambiotte, & Rocklin, 1985; McDonald, Larson, Dansereau, & Spurlin, 1985; Spurlin, Dansereau, Larson, & Brooks, 1984) approach CL by evaluating how well the cooperative facilitates access of knowledge for its individual members on subsequent transfer tasks. For these group-to-individual transfer studies, the original question of what counts for success in CL is reformulated to ask: "What are the conditions in group collaboration that lead to a group member's use of knowledge as an individual?" In general, this line of research indicates positive transfer of knowledge when individuals learn in a cooperative setting when compared to an individual setting.

These more recent approaches in group-to-individual transfer define the assessment of learning over time and thereby focus on an individual's use of previous knowledge. Without provision of a design which focuses on evaluating individual members of a cooperative in subsequent transfer problems, the definition of success relies solely on group performance at the exclusion of trying to understand the conditions necessary for individual access of knowledge.

Another critical aspect of learning measurement is the specification of the control groups, irrespective of whether learning transfer is defined to be part of the CL experimental design. The worst case scenario exists when the design fails to provide any controls and only tests a CL group. Many studies in CL however, provide a mid-range alternative to the worst case. These studies provide an individual control group against which the cooperative group is compared. If the cooperative does better than the individual than that is defined as evidence for CL being effective. However, the group may look better than the individual simply because the strongest member in each group pulls up the score. This problem has rarely been identified in the corpus of CL research, however it has been addressed in the social psychological literature by employing what is termed a "pseudo-group" as a control (Marquart, 1955; McGrath, 1984). A "pseudo-group" is formed by statistically combining individual scores to obtain an 'aggregate mean' to simulate a 'best member' group. If the cooperative condition is better than the pseudo-group condition, then there is evidence for the beneficial effects of CL.

A final aspect of assessment relates to the necessity that learning involves situations which are closely matched to problems which occur in a real-world context. Often CL studies use a context reminiscent of a 'bureaucratic school' wherein student tasks are highly entrenched in verbal, well defined problems and success is only measured in terms of a standardized recall test. Such restrictive contexts of CL can mask the conditions of success and make it difficult for a student to retrieve knowledge when it is needed (Bransford, Sherwood, Hasselbring, Kinzer, & Williams, 1988). Alternatively, everyday problem solving is often interpersonal, ill-structured, incorporates interwoven problems, has extended time frames, occurs with several possible solutions (Meacham & Emont, 1989), involves discovering problems and noticing perceptual attributes of the problem (Bransford, Sherwood, Vye, & Rieser, 1986), and requires students to generate relevant subproblems on their own (Cognition and Technology Group at Vanderbilt, in preparation). Consequently, assessment must strive to begin using learning tasks which are more natural for the student and more relevant for use in everyday problem solving. Rather than

employing standard memory measures (e.g., the Dansereau studies), CL assessment must begin to look at problem solving measures which elicit an intuitive understanding of how a student progresses from goal-to-subgoals-to-solutions. Goldman, Vye, Williams, Rewey, & Pellegrino (1991) describe such an approach wherein they look at how various subgoal feasibilities in a problem space are tested against one another, and evaluated as to how well they satisfy given constraints, in an iterative fashion to determine the best solution path.

A foundation for developing a theoretical approach can begin by looking at the reciprocal interchange between group members engaged in CL problems. The research evaluated in this report is designed to directly respond to this issue by making new theoretical contributions which focus on the cognitive benefits of having people work in groups. These contributions involve empirically testing the relationships among: (a) learning setting (group, pseudo-group, or individual problem solving conditions), (b) quality of solution generated (above average or below average), (c) level of collective induction (dominant, passive, or shared interactions), and (d) presence of metacognitive learning strategies (planning, monitoring, and elaboration activities); to ascertain their influence in successive stages of learning (i.e., acquisition, transfer, and memory performance).² The predicted hypotheses surrounding these relationships can be identified in terms of how a given process effects a learning outcome.

Group Process involving Collective Induction and Generative Learning

Collective induction (Laughlin, 1989) can be thought of as a catalyst which reinforces synergistic interaction among group members such that ideas, knowledge, and strategies are disseminated to each member. Inherently, one member learns something through collective participation with other members above and beyond what they could have learned by themselves. This is a form of generative learning whereby members engage in active discussions and explanations rather than just passively receive information. Such activities allow the generation, refinement, and use of one's own knowledge in new ways rather than

² Acquisition is indicative of the initial problem solving task given to all subjects. Transfer is the time when all subjects are given a problem similar to the acquisition problem and is designed to test transfer of knowledge from the acquisition problem. Recall occurs at least 3 days after the first two time windows and is designed to see how much the subjects retain after their problem solving experiences.

just passively receiving knowledge, e.g., listening to a teacher lecture. (Cognition and Technology Group at Vanderbilt, in preparation). When a student generatively problem solves, their knowledge is less likely to remain inert and is more likely be spontaneously accessed for future endeavors (Bransford et. al., 1988). Each member's generative learning affords them additional insights which are inductively factored back in the group process to increase overall understanding. Hence, the give and take among members causes a synergism to transpire. This may be viewed as the social construction of knowledge (Bereiter & Scardamalia, 1989). A key concept within collective induction is the level of synergy experienced among the group members. It is predicted that groups which contain dominant members may fail to reach the necessary synergy to create collective induction; whereas groups that share together more equally tend to be more synergistic. Without the presence of collective induction, CL may be in jeopardy.

If one assumes that groups do better at solving the acquisition problem than individuals, then -as a basic hypothesis- one can expect to see better individual transfer and recall from students who participated in the CL setting than from those who participated in the individual setting. If CL is better than the pseudo-group for the acquisition problem and if there is better individual transfer for the CL setting, then there is evidence that collective induction was present during acquisition (beyond what the best member could do) and was beneficial for subsequent learning outcomes. The prediction assumes that each group member learned from one another. However, this basic tenet can be examined at a deeper level of group process to see how the level of collective induction present affects transfer and recall performance. Also, the quality of solution, as determined for the acquisition problem, may be a determinant of transfer/recall performance and may present different effects across each learning setting.

A group may be dominated by an individual, as opposed to having a relatively shared responsibility for generating or evaluating ideas. If the dominant member led the group to a good solution, then his or her transfer and recall should be good. One can determine whether the passive partner's individual transfer and recall was better than the mean of the

people who never worked in groups (i.e., the individual-to-individual transfer control group). If yes, then the partner learned something from the other partner. If no, it is difficult to know whether a less-skilled person was selected for the comparison or a more liberal interpretation would be that the passive members of CL groups show no better transfer/recall than individuals who solved the acquisition problem alone. Additionally, the way 'dominance' is determined in a group may vary. Typically, the criteria used to code dominance is either amount of talking or visual observation, or some combination thereof. However, the studies undertaken in this research can compare this traditional measure with a new criteria for dominance: the extent to which one member dominates in the generation of goals for the group. This allows the evaluation of dominance to transpire at a cognitive level to compare with the more traditional criteria.

For those groups which reciprocate and share information on a more equal basis, both members are predicted to show better individual transfer/recall than would be the case for the passive individuals in the non-sharing groups. By analyzing these conditions, collective induction can be more precisely understood.

Group Process involving MetaCognition

Within ill-defined problems, there may be an opportunity for a problem solver to engage in metacognitive strategies (e.g., elaborate ideas, monitor errors, and plan remedial actions). These strategies which allow people to plan and and assess their own cognitive behavior have been shown to facilitate successful individual problem solving (Palincsar & Brown, 1984), as well as group-to-individual transfer (Dansereau, 1988). Taken in the context of CL, there are two ways to view metacognition. The first hypothesis makes the assumption that the group affords its members more opportunities to generate metacognitive strategies than would be the case for the individual learning setting. This view acts to treat metacognition as a measured outcome of problem solving (i.e., in the role of a dependent variable) and as complementary to the previous section on collective induction. In essence, the passive, dominant, shared, pseudo, and individual classifications used to rate acquisition problem performance can be viewed in terms of how

much metacognitive versus cognitive activity they generated by conducting statement analysis of the student's protocols. This acts as a unique kind of problem solving measure as it provides a measure of cognition within a learning setting, contingent on the assessed level of collective induction.

The second hypothesis involving metacognition assumes that different types of strategies may affect each stage of learning in different ways. This view treats metacognition as an independent variable which is capable of influencing problem solving and subsequent learning outcomes. For example, the Larson et.al. (1985) study revealed that when groups engaged in error monitoring, they showed better performance for an acquisition task than groups which engaged in elaboration learning strategies. However, on an individual transfer task, the individuals which had participated in elaborative groups outperformed those individuals which had been in the error monitoring groups. From this result, one could expect to see different learning outcomes for each dominant strategy. These results predict that the monitoring activity may prove to be more effective for acquisition, but the other types of strategies are essentially unexplored territory.

Each student's problem solving protocol for the acquisition problem will be analyzed to determine the dominant activity type (i.e., whether each idea unit in their transcript is indicative of "planning, monitoring, or remediating something" associated with the problem). Just like the level of collective induction acts as a predictor for determining individual transfer/recall, dominant activity type can also be used to see whether one strategy affects performance differently than another strategy. The influence of metacognitive learning strategies can be more precisely defined by analyzing their interaction with learning setting. Predictions would suggest that in general the cooperative learning setting would enhance all the strategies given the assumption that groups generate more activities beyond what the individual could do. Research by Goldman, Vye, Williams, Rewey, & Pellegrino (1991) suggests that when students solve complex problems they have difficulty attending to conceptual or executional errors. Therein, the group may afford catching another's error more effectively than if that person solved the

problem alone. However, based on the Larson et. al (1985) study there may be an interaction wherein monitoring activity occurring in the cooperative learning setting would increase acquisition, but not transfer/recall performance. The predictions with respect to planning or other activities are unexplored territory so they are somewhat tentative.

Based on a response to the practical, methodological, and theoretical issues just identified, a specific direction in research can be established which adds unique contributions to the literature. By addressing each of the identified variables at different evaluative stages of learning, an understanding of what counts for success in CL can ensue.

CHAPTER II

METHODS

Subjects

A total of fifty-six subjects were randomly assigned to two experimental conditions, cooperative learning and individual learning, and served in each stage (i.e., study) of problem solving: acquisition, transfer, and recall. All Ss were paid university students acquired through Logicon Technical Services, Inc. at the Armstrong Aerospace Medical Research Laboratory. Certain restrictions were placed on the selection of Ss to insure consistency and level of performance across the subject pool. Ss were restricted to only include those students within the 18 - 30 year old age range. The request for Ss also indicated that the subject must be able to read and have basic math skills. Pilot studies determined that the vast majority of university students could at least make an attempt to provide some solution to the problems utilized for this study. Therein, special criteria indicative of mathematical advancement (e.g., SAT math scores) were not used for this study. Ss were required to also have self-reported or corrected-to-normal 20/20 vision and allowed to wear glasses/contact lenses. Due to the nature of the content problem, any subject which had received exposure or graduated from pilot's training was excluded from the studies. There were no gender or handedness restrictions levied on the subject pool.

Please refer to Figure 1 which provides an overview of the subject requirements and design for the problem solving studies.

Design

A perusal of Figure 1 indicates that all Ss participated in two sessions which compose the three stages of study. For an activity timeline of both sessions, please refer to Figure 2. Session 1 is inclusive of the acquisition and transfer problems and lasts for approximately

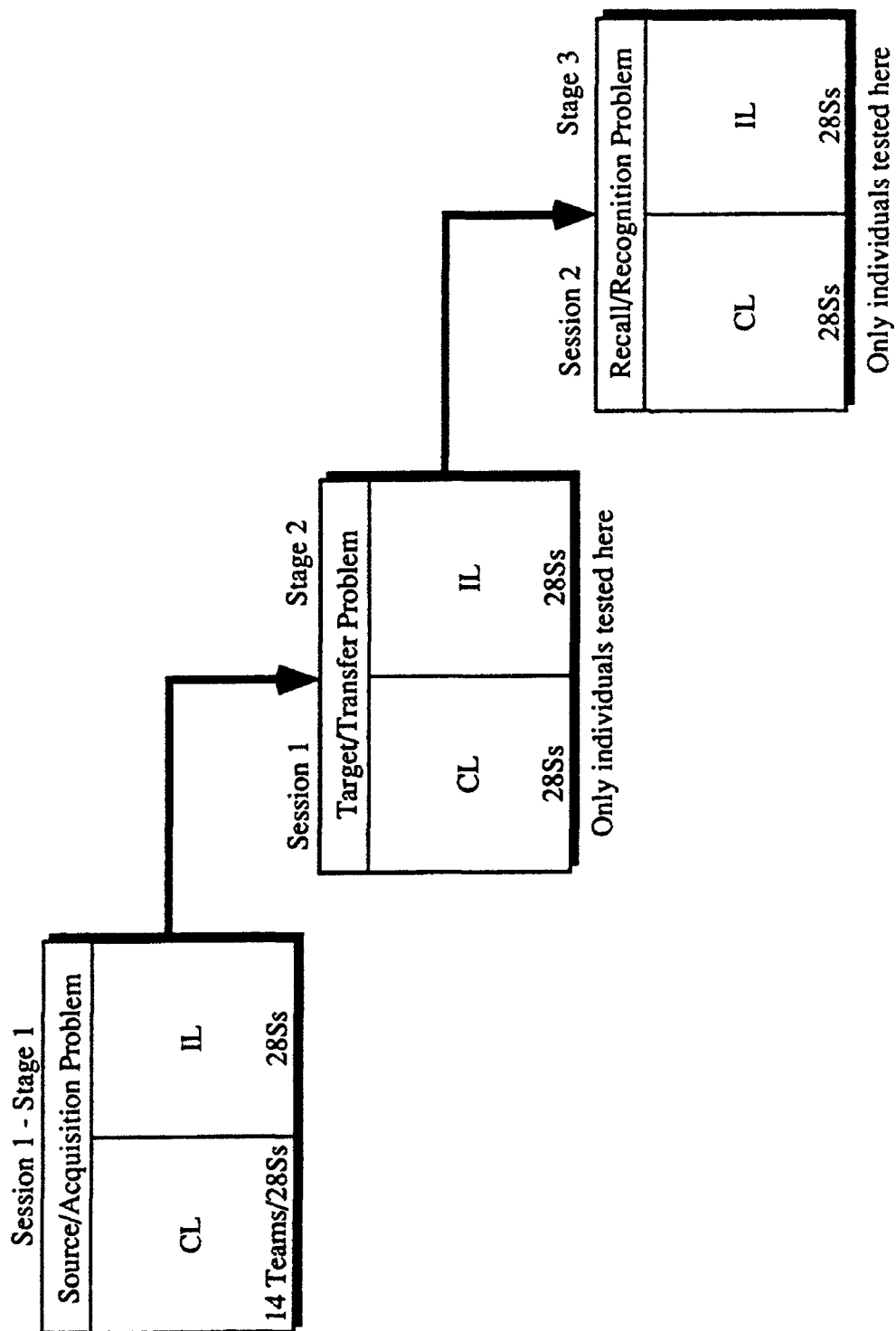


Fig. 1 Experimental Design Overview

2.5 to 3 hours. Session 2 occurs at a minimum of 3 days after session 1, lasts for approximately 1 hour, and includes only the recall/recognition problem.³ For the acquisition problem, 14 teams (composed of 2 people each) served in the cooperative learning condition and 28 Ss served in the individual learning condition. All of the Ss were individually given the transfer problem to solve. If a subject served within the group condition for the acquisition, they now receive the transfer problem as an individual only. This is representative of the group-to-individual transfer paradigm. If a subject served as an individual in the acquisition problem, they still continue solving the transfer problem as an individual. This provides the control condition, termed individual-to-individual transfer, which may be compared to the group-to-individual transfer condition to evaluate the affects of cooperative learning in analogical problem solving.⁴ Appendix A, experimental materials, and Appendix B, data analysis plan, provide necessary details surrounding the experimental design, dependent measures, and stages of analysis.

Task Description

The focus of the experimental procedure is based on the use of the Jasper task, *The Adventures of Jasper Woodbury: Rescue at Boone's Meadow*. This complex, multi-step problem is presented through the use of a laser video disc player and incorporates a search and rescue task involving an ultralight airplane. The goal behind the creation of Jasper was to implement an ill-structured planning task which affords students the opportunity to identify, define, and discover their own problems within a natural domain (i.e., a macrocontext), while taking temporal, spatial, and practical interdependencies into account. This macrocontext can be

³ Note that session 2 could occur up to as much as 5 days after the initial session 1 occurrence. In several cases, Ss were not able to be brought back until as much as 9 days later. In these cases, the means of these extreme points were compared with the means of the remainder of Ss within the appropriate experimental condition to see if they were significantly different. Results indicated that these extreme cases could be included without detrimental effects to the data set.

⁴ Within Figure 1 note that an additional comparison will be the use of statistical pseudo-teams. Basically pseudo-teams allow one to create "best team" models to determine if in fact any 'collective induction' is present beyond just what the best team would do. The best team model randomly creates 14 teams from the 28 Ss used for the individual learning condition and then figures a statistical aggregate mean for the pseudo-teams formed. If the cooperative learning team is better than the pseudo-team then this is an indication that collective induction has in fact been obtained; however, if the pseudo-team mean is better than the cooperative learning group then this suggests that the CL group does well only because of the capabilities of individual team members and not the collective induction of those team members. Other statistical models of the group may be formed as well (e.g. the worst-team model) for comparison purposes. Because a statistical aggregate is used, this necessitated requirements for the 28 Ss so we could compose 14 'pooled teams'.

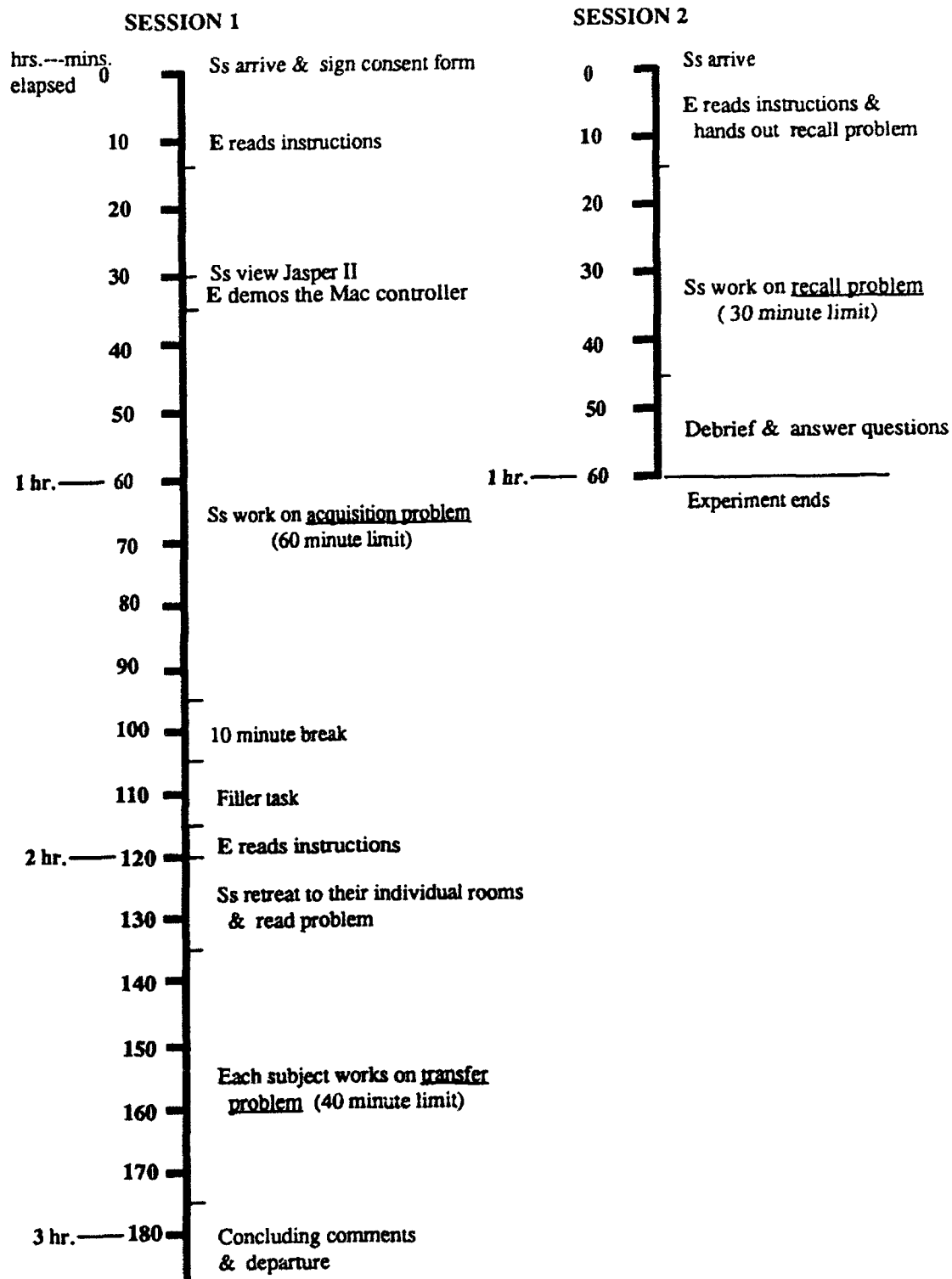


Fig. 2. Experimental Activity Timeline

mutually explored by groups or individuals and shared across a variety of subject backgrounds. As such, it "invites the subject to think." Once the problems are identified, they may be solved by using middle-school level mathematics. The videodisc allows students to experience changes in their perceptions by allowing them to familiarize themselves with the features by immediately accessing video segments for potential contrasts and comparisons. The Jasper macrocontext serves as the acquisition task in the group-to-individual transfer paradigm.

Repsaj, the individual transfer task in this paradigm, is represented as a verbal analogue of the Jasper problem.⁹ The Repsaj task represents a word story format which is similar in storyline and solution procedure to Jasper. The underlying structure of Repsaj is the same as Jasper, but the surface structure and mode of representation vary. Repsaj uses the same kind of problem as Jasper but places it in a somewhat different domain with different surface object-attributes. For example, the Jasper domain involves an Ultralight airplane being used in search and rescue to save a disabled eagle shot in a forest. The goal of this problem is to find the most efficient way to get the eagle to the veterinarian before it dies. In contrast, the Repsaj domain involves a lightweight plane used to rescue an injured Air Force officer who has contracted frostbite while on maneuvers in a remote region of Canada. The goal of this problem is to find the most efficient way to rescue the officer and transport her to the nearest medical facility. The surface themes that relate the two problems are similar rather than dissimilar (as would be the case in a remote analogy problem). Although the domains have different specifications they are connected by the fact that they both involve operations and specific knowledge of aircraft and their flying capabilities, as well as rescue missions. In each problem, the solver must pay attention to the characteristics of the airplanes (e.g., payload capacity) and other vehicles involved to: 1.) know the conditions, and 2.) create the plans which lead to the most efficient tradeoffs at the right point in time. As there are many similarities between the two problems, they may be classified as close analogies of each other. When Repsaj follows Jasper, we have set up the situation for near-term transfer.

Materials and Apparatus

Materials are designated according to the acquisition, transfer, and recall/recognition stages

⁹The text for both Jasper and the Repsaj problems are available upon request from the author.

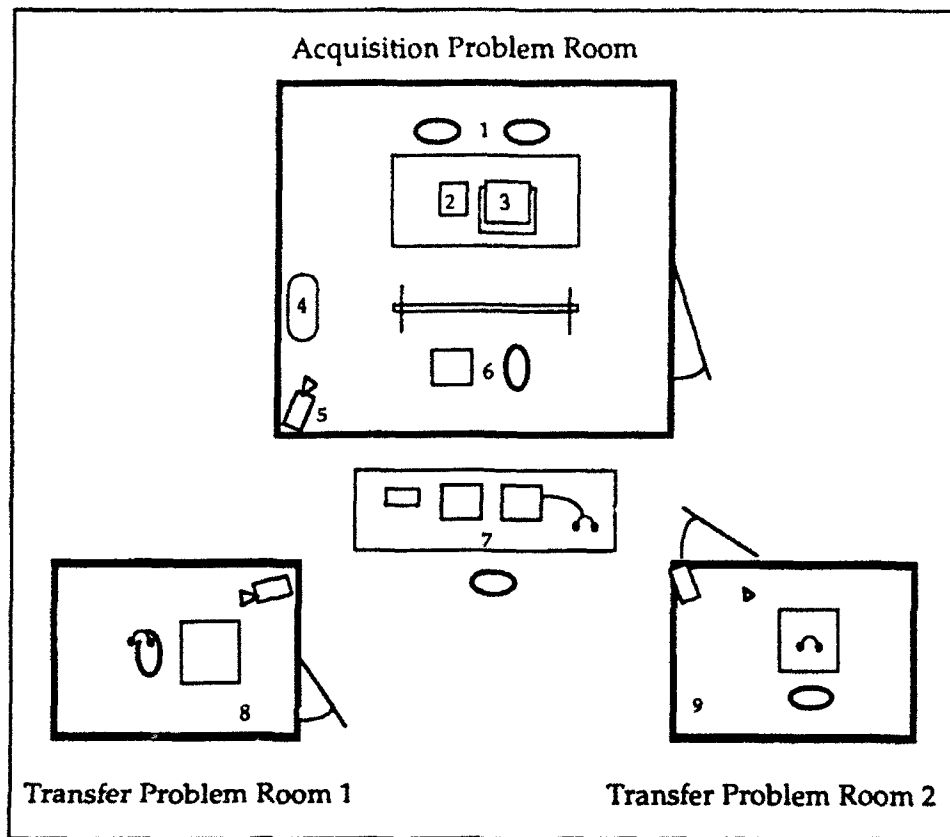
of study. The acquisition problem materials consist of the Jasper laser videodisc and an auditory tape used to show Ss an example of a person 'thinking aloud'. The transfer problem materials consist of a text-only version of Repsaj, a biographical form (used as a 'filler segment' in between the acquisition and transfer stages), a Ss' worksheet (for working on their problem), and a Ss' answer sheet (to record their final answers). The recall /recognition problem materials include a test booklet which incorporates 40 questions (either multiple choice or fill-in-the-blank) and written instructions for all test components.

The apparatus used includes a Macintosh Plus® computer system (including a 45 megabyte hard disc drive) which is interfaced to 1.) a Pioneer 2200® random access, laserdisc player and 2.) a Magnavox® 14 inch color monitor. This video workstation (for use by the subject) has the capacity to display laser videodiscs, text, graphics, and interactively control access to the laserdisc through the computer keyboard or mouse. A timer-signal is used to collect timing data on the subject. Other apparatus included three 14 inch color monitors for the experimenter's station, a clock for Ss to use, and three color video cameras with an integrated microphone system which is linked to a VCR to record Ss problem solving behavior. A program resident within the Mac was designed to record all the commands an individual or group makes while interacting with the laserdisc-based Jasper problem. These computer records can then serve as evidence to review the extent/content of perceptual contrasts that a person makes while solving this acquisition problem.

Please refer to Figure 3 which provides an experimental facility layout for all problem solving stages. The layout contains a large experimental room designed for the acquisition problem and recall/recognition problems, and two smaller experimenter rooms designed for the individual transfer problem. All rooms were conducive for discussion and problem solving activities.

Procedure

The final implemented procedure resulted from repeated testing of pilot Ss. The experimenter's script/instruction set implements the experimental procedure. The experimental procedure spans across 2 sessions: problem solving and recall. Session 1 includes the acquisition, filler, and transfer tasks while session 2 includes only the memory recognition/recall



1. Individual or Group sits here
2. Mac Controiler
3. Laserdisc Player/Color Monitor
4. VCR recorder
5. Video Camera
6. E's monitor/workstation for acquisition
7. E's audio-visual monitor for each individual subject in transfer problem room
8. Subject at desk solving transfer problem - rooom 1
9. Subject at desk solving transfer problem - rooom 2

Fig. 3 Experimental Facility Layout

task⁴. Please refer to Figure 2 presented earlier which describes the schedule/timeline of the experimental procedures. The problem solving session could take as long as 3 hours while the recall session could take as long as 1 hour. The recall session occurred a minimum of 3 days after the problem solving session. Ss are debriefed only after completion of their memory task.

Prior to arriving at the experiment, Ss are randomly assigned to either the individual or cooperative learning conditions accordingly. Upon arriving at the experimental setting for Session 1, Ss are asked to sign consent forms. After each 2-person team or individual has been positioned at their video workstation; they are briefed about the experiment, and presented the proper set of instructions by the experimenter.

The instructions assigned to the cooperative learning condition were essentially the same as the individual condition. Appendix A provides an example of the individual instruction set. The instructions emphasize the necessity of creating individual and cooperative learning settings which present unstructured conditions of learning. That is, an individual or group member was not trained in specific rules of engagement for solving the Jasper or Repsaj problems. An individual or group was given the freedom to design their own strategies to solve the problems. The instructions requested all Ss to talk aloud as they solved the problem. The groups received no special incentives to work together other than the problems themselves. They were presented the problem challenge within the videodisc using the same instructions as given to individuals. Thus, groups were not told what each member should do, when they should do it, or given specific roles to play. Their engagement of the problem was at their own discretion to be determined in a manner which was most suitable for their effectiveness to solve the problem. The main thrust for individuals and teams was to solve the problem in the best way possible in the shortest amount of time. The team instructions might be viewed as if they were instructions to an individual with just another person present. As a consequence, cooperative learning was prototyped to represent a naturally occurring learning group which decides its own strategy, rules, and allocation of resources for problem solving (within the confines of the instruction set which applies to individuals as well). The assumptions used for this form of cooperative learning reinforce the view that learning can occur in the context of everyday problem solving without a large debt of preconceived training or stratification used to assign group process in

⁴ The Repsaj problem text, experimenter's script/instruction set, subjects' consent form, recall/recognition test materials, and the subjects' final debriefing are available in Appendix A.

action. Although cooperative learning is often seen as a structured process and can realistically be produced in this form, the approach in this research is to generate the benefits of learning without some of the overhead involved.

The instructions emphasize the importance of showing all ones work on paper, despite whether a subject feels it represented an incorrect solution. Ss are asked to number their solution steps in the order in which they proceed to help assist in coding their verbal protocols. The instructions indicate to Ss that they will be timed but emphasize the need to produce the best quality solution. They focus on the use of protocol analysis and instruct Ss on how to "think aloud." The experimenter plays an audio cassette as an example of a person "thinking aloud". Part of the instructional period provides brief training on how to access segments of the videodisc via the use of the mouse in conjunction with a visual display (i.e., a "table of contents" which shows a given segment and its associated video frame number sequences) on the Mac screen. The Ss may compare/contrast different segments of the video without restriction.

The instructions for the transfer, filler, and memory task are pretty much self-explanatory. For transfer, Ss are instructed to come up with the best answer within the designated time window. One other consideration emphasized is that the time window for the target task is 20 minutes less than allotted for the source task. This requires Ss to use their prior knowledge under more restrictive time windows and places greater emphasis and amplification on those conditions which prime analogical transfer under real world conditions.

After a team or an individual receives their initial instructions, the full length Jasper video (approximately 17 minutes in length) is presented without interruption. Ss are asked not to take notes during presentation time. After the problem has been presented, a timer initializes recording of Ss' behavior and they begin their problem solving time window.⁷ After 60 minutes, Ss are asked to stop their problem solving activities. When Ss are done solving the acquisition problem, they signal the experimenter. The experimenter asks them to give a summary of their solution steps and then they are released from the acquisition problem. At this point, Ss are required to take a 10 minute break. After the break, all Ss return to the large experimental room to participate in the filler task.

⁷ In, actuality, after the video ends, the experimenter reinforces the instruction on how to control the videodisc player. Then, when the subject is comfortable, the timer is initiated and the time window for problem solving begins.

The filler task takes about 5-10 minutes and acts as a momentary interference factor before starting the transfer problem.⁸ The experimenter informs Ss that the filler task is a survey required by the experimenters to obtain biographical and individualistic problem solving information from the Ss.

The transfer task is presented entirely as a verbal story problem for all Ss and is solved individually. Subjects are given instructions which describe the transfer task and what is required of them. Each subject is given about 5-10 minutes to read the problem, then recording of their behavior begins as the experimenter signals they may begin working on the transfer. The Ss are allowed a maximum of 40 minutes to complete this task. If they complete the task before the 40 minutes are up, they may signal the experimenter that they have completed the problem.⁹ After the transfer task, they are required to turn in all their written materials and reminded to return in 3 days for Session 2.

Upon arriving for the recall session (at the large experimental room), Ss are given a test booklet which contains the memory recall/recognition task. The experimenter explains the test and then asks Ss to begin. At this point, a timer is initiated to record Ss' response times. Ss have up to 30 minutes to complete the booklet. Note that as many as 4 Ss can be tested simultaneously for this task given that they meet the requirement that the memory test be at least 3 days after session 1. When Ss are done with the recall task, they are debriefed and then dismissed. This completes the experimental procedure.¹⁰

⁸ It represents a technique which requires the subject to access information which was not previously encoded under the various acquisition conditions. In essence, it wipes clean any information in short term memory from the source problem; and hence, acts as a safeguard to properly assess transfer.

⁹ Piloting procedures demonstrated that one experimenter could successfully monitor the two individual Ss who simultaneously solve the Repsaj problem in their separate rooms.

¹⁰ The 3-day delay is the "acid-test" indicative of which source conditions enhance memory for acquisition and transfer problem knowledge the most. The delay is to emulate how well we remember knowledge previously used and whether original conditions of acquisition weaken or enhance this memory.

CHAPTER III

ANALYSIS OF JASPER/REPSAJ PROBLEMS

The reporting of results will progress from looking first at the basic issue of whether groups do better than individuals for the Jasper problem. Further examination addresses detailed issues involving collective induction, a new criterion to rate collective induction, and metacognition within the acquisition problem. After the acquisition results are reported, the Repsaj results span the same progression beginning with the basic issue and proceeding with each successive issue.

Each of the major issues addressed contains their own separate results/discussion section. These sections are supported by four analysis platforms each of which contain an acquisition (A) and transfer (T) component : A/T-1 (addresses learning setting/collective induction - defined by talking activity), A/T-2 (addresses learning setting/collective induction - defined by cognitive contributions), A/T-3 (addresses learning setting x quality of solution), and A/T-4 (addresses learning setting x metacognitive activity type). Each of these platforms analyzes three major clusters of dependent variables: C1 (problem space measures), C2 (statement type measures), and C3 (performance measures). The transfer components also analyze a fourth cluster: C4 (recall/recognition measures). The very top level of analysis shows the effects of the main independent variables on each of these clusters by performing a MANOVA on each cluster of measures. Please refer to Appendix B for a detailed look at these measures. The problem space and statement analyses employ procedures currently used by the Cognition and Technology Group at Vanderbilt (see Goldman, Vye, Williams, Rewey, & Pellegrino, 1991).

For each protocol analysis performed, cross-reliability checks between raters were conducted in accordance with the procedure used by O'Donnell, Dansereau, Hythecker, Hall, Skaggs, Lambiotte, & Young (1988). Results showed an 88% correlation for the

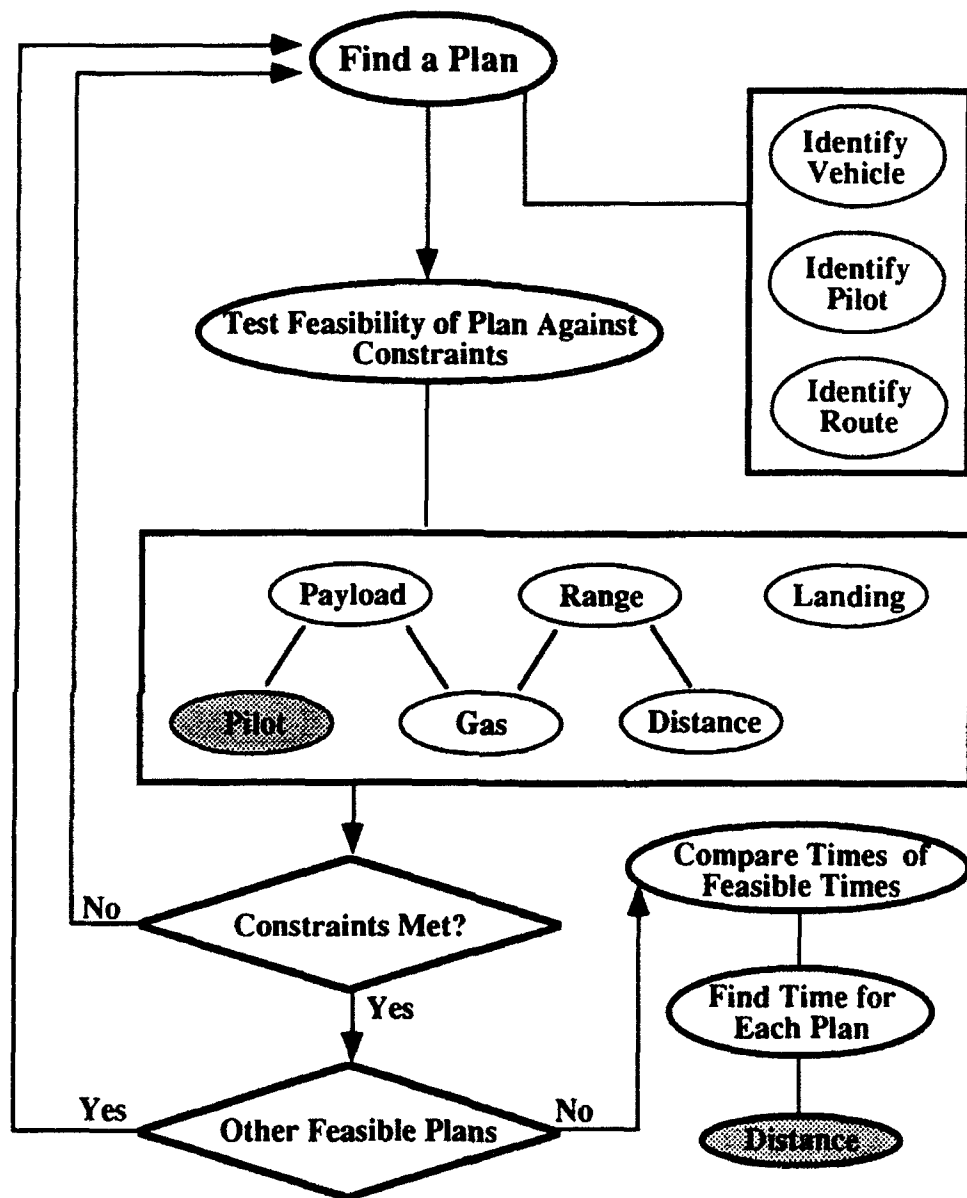
problem space protocol analysis, 96% correlation for the statement encoding (Pearson $r = .96$, $p < .0005$), and a 97% correlation for the metacognitive activities type protocol analysis (Pearson $r = .97$, $p < .03$).

The scoring of a group or individual transcript for the problem space and statement protocol analysis is based on evaluation of the problem elements occurring and statements in the transcript. For the Jasper problem space analysis involving the summary measure, % of problem elements solved, the presence of particular solution space constraints and optimizing elements are scored by rating the transcript as the product of an individual's or a group's problem solving process. For the group, either member may identify a particular element (eg., payload solved) and the group receives credit for its occurrence. Their transcript is analyzed as a single product as if it were an individual transcript. The scoring for solution space constraints or optimizing elements represents the % of individuals (for the individual condition) or % of groups (for the group condition) which obtained the problem element under question. Again the group's transcript is treated as a single product which each member jointly contributes to. For the Jasper statement analysis, each statement is classified as indicative of a particular kind of problem solving activity regardless of whether it was an individual or group transcript. In summary, the transcript of the group is evaluated as if it were an individual transcript. Evaluating group and individual transcripts in the same manner allows direct comparison of problem solving results. Refer to the Appendix B, data analysis plan, for more information.

Although many specific comparisons and analyses were performed using these measures, only those analyses which directly support each issue are reported.¹¹ The reporting structure places the most emphasis on the *problem space cluster*. Primarily, results from the other clusters will be considered as supplemental analyses and are reported as supporting evidence to the point being emphasized.

To lend some order to the reporting of this complex analysis we first address the major issues by looking at the problem space protocol analysis. The protocols were scored in accordance with the planning net elements shown in Figure 4. Because Jasper

¹¹ These additional analyses may be obtained from the author by request.



Challenge: Find the quickest way to rescue the eagle.
How long will that take?

and Repsaj are analogues of each other, the same structural elements are consistent across problems although the surface level objects in Repsaj vary (eg., Jasper involves the rescue of a wounded eagle in the forest, whereas Repsaj involves the rescue of a wounded military officer in a snow covered region of the mountains). The planning net shows that to determine the feasibility of a plan a person must consider basic constraints such as payload, range, and time as related to the goal of finding the fastest way to rescue a wounded eagle. This involves understanding specific subgoals such as: What route is available to save the eagle? How much fuel do I have? Who is available to drive a vehicle in a rescue attempt? If I fly the ultralight, do I have enough landing space at the rescue site? Will the weight placed in the vehicle be greater than its acceptable payload?

In order to obtain the best answer, problem solvers must generate different plans or modify plans to utilize multiple pilots, vehicles, or routes, or compare times for rescue plans, when any one of the constraints is exceeded. These problem space factors involve consideration of the complex interrelationships of the problem space and are referred to as 'optimizing solution elements'. The testing of these new plans which includes the optimizing solution elements is then compared with the problem's initial requirements until the problem solvers iterate the best solution. This requires calculating and comparing execution times as plans are generated. Thus, the problem space incorporates a number of different elements which can be assessed in order to evaluate a problem solver's successful path to solution.

Our global-to-local analysis (and report) of the data includes three distinct views of the problem space. First, we take a wholistic view by looking at the primary summary variable. For Jasper this is defined as the % of problem elements solved. This variable portrays a total score in the problem space as it represents how well subjects did by scoring the % of problem elements they obtained out of the total available. This summative variable includes whether subjects mentioned, attempted, or solved the elements involved for each feasible route (payload, range, and time) and their consideration of each identified optimizing solution element. Each element had equal weight in computing the % they obtained out of the total possible. The primary summative variable for Repsaj is the % of

problem elements transferred. This represents the % of the elements initially obtained in the Jasper which were maintained for Repsaj. For example, if subjects mentioned payload in Jasper and then mentioned it again in Repsaj, this would indicate that they had transferred this single element. The score thus represents the total amount of elements transferred from Jasper-to-Repsaj.

The next, more detailed view of the data (for both Jasper and Repsaj) analyzes how well subjects did on attempting, mentioning, and solving payload, range, and time constraints. This view explicates problem solving on less complex aspects of the problem space. Finally, an analysis of how well problem solvers did on the optimizing elements is presented. This view highlights differences for the more complex parts of the problem space. Any other data from the statement analysis, performance, or recall/recognition measures that corroborate or clarify the problem space measures are also presented.

A Brief Overview

A quick survey of results show that groups do better than individuals (and pseudo-groups) on the Jasper problem space. Groups spend more time generating different metacognitive strategies to solve the more complex elements of the problem, while individuals spend more time working in the macrocontext. On Repsaj problem solving, the time groups spend in metacognition serves to help them solve the most complex parts of Repsaj. However, individuals transfer more total amount of elements from Jasper than groups. Apparently the time spent with the details of all the problem and multiple searches of the perceptual context enhanced this aspect of their problem solving on Repsaj.

Additional transfer results testing the role of quality of solution suggest that above average group members or above average individuals on Jasper still maintain that advantage over below average group members or below average individuals on Repsaj. Other findings showed that defining collective induction by the amount of talking in teams may not be as faithful to the hypothesis testing as a new criterion (based on cognitive contributions derived from protocol analysis).

The distinctive roles of experiencing a perceptual macrocontext, metacognition, and

quality of solution - in conjunction with learning setting- are explained as major conditions that contribute to understanding 'what' counts for success in cooperative learning. The forthcoming sections explain these results in detail and specifically outline more extensive results for collective induction and metacognition.

Understanding the Effects of Learning Setting in the Jasper Acquisition Problem

Results

Learning setting analysis. The first objective of these analyses was to look at the issue of *learning setting* and to see the various factors which contributed to differences in conditions. The primary summative variable of Cluster 1, % of problem space elements obtained, showed a significant main effect of learning setting ($F(2,53) = 3.21, p < 0.008$). Also, according to Hotelling-Lawly's criteria, the MANOVA results showed there was an overall significant main effect for learning setting for Cluster 2, statement type measures, ($F(10,96) = 2.58, p < 0.008$); and Cluster 3, performance measures, ($F(6,98) = 2.76, p < 0.016$). Based on these findings, we then investigated whether groups do better than individuals. Individual comparison tests performed on the primary variable, shown in Figure 5, revealed that groups ($m = 75.51$) do better than individuals ($m = 61.48$), ($t = 2.41, p = 0.02$). Although the mean for groups ($m = 75.51$) was higher than pseudo-groups ($m = 70.40$), results failed to reach significance ($t = 1.54, p = 0.13$).

For a closer look at the data, Chi-Square tests were used to evaluate the % of subjects in each group, individual, or pseudo-group condition who mentioned, attempted, and solved range, payload, and time constraints within their plans. These results are plotted in Figure 6. There were no significant differences between groups and individuals for evaluating the feasibility of the plans they generated. In general, groups, individuals, and pseudo-groups tend to do quite well on mentioning and attempting elements necessary to make feasible plans. In fact, most subjects mentioned payload, range, and time. These measures represent the least complex parts of the planning net. As expected, the solution constraints were much harder to obtain than either the mention or attempt constraints. It is

this first indication of Jasper complexity that significant differences were found. The Chi-Square test revealed that a higher percentage of groups ($m = 64.3\%$) solve for the payload problem space element when compared to individuals ($m = 25\%$), ($X^2 = 3.63, p = 0.05$). Although groups do better than individuals for the 'range solved' constraint, this difference was not significant. The results for 'time solved' were so low for every condition that no differences were evident. The calculation aspects for range and time are more difficult than for payload solved, but payload solved requires inclusion of items easily forgotten (eg., the weight of the eagle rescued). Hence, these results suggest that groups help consider more of these forgotten items than individuals but the group may not facilitate improvement in calculational abilities. These results coincide with the results obtained by the Cognition and Technology Group at Vanderbilt (CTGV) when testing college students and sixth grade students. CTGV (1992) found the mention and attempt elements relatively easy for all students but found that the solution elements to be much harder for students to come by.

Progressing to the most complex aspects of the solution space, this trend continues as we analyzed the optimizing elements of the problem space. These results are shown in Figure 7. A higher percentage of groups ($m = 78.6\%$) are significantly more likely to consider multiple rescue routes than individuals ($m = 32.1\%$), ($X^2 = 4.09, p = 0.04$). Groups also do better than individuals in consideration of 'multiple vehicles' and 'compare times' optimization elements although these comparisons failed to reach significance. The rates for individuals are much lower than obtained for the feasibility constraints. This replicates the findings obtained by CTGV for the college students however an interesting comparison also arises. Their college students solved Jasper as individuals and in essence did no better than the six grade students in generating new plans to create the best solution possible, even though this was the prime objective of the problem. In contrast, this study shows that when college students are placed in a group, their ability to generate new plans, based on consideration of the optimizing elements, was a vast improvement over individual students solving Jasper. Hence, one of the more fascinating findings of the study was the likelihood that groups do better on the more difficult aspects of the Jasper problem.

Pseudo-group analysis. Although these findings show groups performing better than individuals for Jasper, they may simply be due to superior performance by the best member of the group. To see if the group was effective due to the induction taking place between members, the group condition was compared with the pseudo-group condition to see if the group performed better. For the primary summary variable, the mean for groups ($m = 75.51$) was higher than for pseudo-groups ($m = 70.40$) but results failed to reach significance ($t = 1.54, p = 0.13$), refer to Figure 5. But, when we look at the more detailed comparisons for the optimizing elements, we find that a higher percentage of groups ($m = 78.6\%$) are significantly more likely to consider multiple rescue routes than pseudo-groups ($m = 21.4\%$), ($X^2 = 4.57, p = 0.03$), refer to Figure 7. This shows that for one of the most complex aspects of Jasper, under the most stringent test involving the pseudo-group control condition, there is an advantage gained by participating in the cooperative learning setting.

Supplemental analysis. In addition to the problem space cluster, there are complimentary findings in Cluster 2, statement analysis, which are important to understand what contributes to successful cooperative learning. Each transcript statement was scored in terms of whether it was representative of the one of the following categories: goal, state, mean, outcome, metacognitive monitoring, misconception, and 'other'. For example, the phrase "I want to choose a vehicle" would be scored as a goal, or "There are no roads leading to Boone's Meadow" is a state, or "How can I figure out if there is gas in that can or not?" is metacognitive statement. The statement analysis shows the % of statements (out of all the possible statements) encoded for a given category. Hence, each individual or group transcript could be reviewed to see the relative percentage of these statement categories which were obtained. For example, an individual's transcript may have consisted of 10% goal statements, 25% state statements, 5% means statements and so on. The interpretation of these differing patterns of activity may highlight why groups proved to be superior on the Jasper acquisition problem. In fact, this was the case.

Activities such as identifying states, defining the means to relate states with goals,

and calculating outcomes are more indicative of activities which center on stating facts, procedures, and solutions and as such are highly related to the details of the Jasper task at hand. Please refer to Figure 8 for the following set of results. For % of states generated, individuals ($m = 16.79$) produced more than groups ($m = 12.64$), ($t = 2.31, p = 0.02$). Pseudo-groups ($m = 18.65$) also produced more of these statements than groups ($m = 12.64$), ($t = 3.62, p = 0.003$). This trend is maintained for % of means generated. Individuals ($m = 15.76$) produced more than groups ($m = 12.86$), ($t = 1.99, p = 0.05$). Pseudo-groups ($m = 16.80$) also produced more than groups ($m = 12.86$), ($t = 2.35, p = 0.02$). The trend continues for % of outcomes generated as individuals ($m = 16.66$) produced more than groups ($m = 12.21$), ($t = 2.65, p = 0.01$). Pseudo-groups ($m = 18.86$) also produced more than groups ($m = 12.21$), ($t = 3.44, p = 0.001$). Thus, the analysis found that individuals and pseudo-groups generate more of these types of statements in contrast to groups.

By comparison, activities such as generating goals, identifying misconceptions, pursuing metacognitive monitoring, and 'other' activities center on problem identification, argumentation, affective states, catching errors, and planning. These kind of statements focus beyond the details of the problem per se and emphasize some of the problem solving strategies used to assimilate the problem. The analysis revealed a partially reverse pattern for these activities as shown in Figure 9. For % of goals and misconceptions generated, there were no significant differences among the learning setting conditions. However, for % of metacognitive monitoring statements generated, groups ($m = 34.45$) produced more than individuals ($m = 26.17$), ($t = 3.18, p = 0.002$). Groups ($m = 34.45$) also produced more than pseudo-groups ($m = 26.00$), ($t = 2.81, p = 0.007$). This trend continued for % 'other' statements generated as Groups ($m = 17.16$) produced more than individuals ($m = 12.46$), ($t = 3.18, p = 0.05$). Groups ($m = 17.16$) also produced more than pseudo-groups ($m = 7.39$), ($t = 2.12, p = 0.04$). These statement analyses show clear differences in how groups vary from individuals on their problem solving activities.

The Cluster 3 measure, number of initiatives recorded on the laserdisc, nicely complements the statement analysis as it also highlights differences in the pattern of

activities between groups and individuals. The measure represents the extent to which a subject perceptually experienced and utilized the videodisc for contrasts, comparisons, and searches for relevant information in the Jasper macrocontext. Figure 10 shows that individuals ($m = 27.64$) accessed the Jasper videodisc more than groups ($m = 17.54$), ($t = 2.49, p = 0.01$). Additionally, pseudo-groups ($m = 28.78$) accessed the Jasper videodisc more than groups ($m = 17.54$), ($t = 2.42, p = 0.02$). Therein, this performance measure reinforces the idea that individuals and even pseudo-groups emphasize different approaches to Jasper problem solving.

Discussion

In the introduction chapter, two primary factors were suggested as salient for understanding cooperative problem solving: a) the cognitive benefits of having people naturally work together in groups, and b) affording learners to generate, discover, and notice the perceptual aspects of knowledge in a macrocontext. The first factor centers on collective induction and metacognitive learning strategies. The second factor derived from research which suggests that if knowledge is acquired in a problem orientation within a perceptual context, then there is a greater chance that knowledge can be spontaneously accessed during 'uninformed' conditions (ie., a person is not told what to do or recall), see Bransford et. al. (1988). The analyses revealed that indeed these factors help to clarify what counts for success in CL. The results of our study clearly support previous work in cooperative learning (Johnson et. al., 1981; Dansereau, 1988) and reinforce our hypothesis that groups would -in general- do better on the Jasper problem than individuals. This coincides with recent CTGV (1992) findings which suggest that individuals need some form of support mechanism to generate plans to optimize their solutions. It appears that the help of another problem solver (factor a) acts to provide a synergy which is most useful for consideration of the most complex, optimizing elements of Jasper. Furthermore, our use of *pseudo-groups found collective induction* present as a catalyst which allows groups to even perform better than what a 'best member' group could achieve. Hence, these findings suggest that there are cognitive benefits which ensue while working in a situated

cooperative learning setting.

In contrast to these findings which trumpet the success of groups, the research provides a clarification on the use of the macrocontext (factor b) by groups versus individuals. Our original hypothesis pointed to the role of a macrocontext as a basis to experience a problem, thus providing the opportunity for problem solvers to notice and generate attributes relevant to the problem. Our results show that individuals actually spent more time with the macrocontext than was the case for group problem solvers. Consequently, individuals (and pseudo-groups) have more perceptual learning experiences and maintain a stricter focus on problem details. Presumably, this approach would allow a problem solver to condition their knowledge to perceptual anchors to create a forward chaining effect across similar contexts (Greeno, Smith, & Moore, in press). This would allow a problem solver to recognize conditions in future situations which have similar attributes as those experienced in the original situation, thus resulting in the spontaneous reuse of previous knowledge.

In contrast to this approach, it appears that groups rely on metacognitive strategies and although they use Jasper as a perceptual anchor for problem solving, they explore it much less than individuals. One can interpret these results by suggesting that group process is very distributive. The external group memory acts to obviate access of the videodisc for retrieval of information due to each member contributing what they know. Thereby, the group has more discussion about the alternative plans regarding the problem space but explores the perceptual space less. The 'external memory' reduces the necessity for any given member to have to rely on limited generation of knowledge (and thereby retreat to the macrocontext to retrieve the data required to solve the problem). Our statement analysis supported this finding by showing that individuals engage in activities which are highly related to the Jasper details and facts; whereas groups are more distributive in their approach to problem solving and focus more on metacognitive strategies. Whether acquiring knowledge under these differing strategies is of any value will be taken up by evaluating the success of each learning setting in the Repsaj transfer problem.

By addressing learning setting as the first major research issue, we were able to uncover significant differences in the approach to Jasper by groups and individuals that highlight three components of problem solving: collective induction, metacognition, and the exploration of a perceptual-based context. The remainder of the analyses and discussion will investigate these components in much greater depth to fully elaborate what counts for success in cooperative learning.

Understanding the Effects of Collective Induction in the Jasper Acquisition Problem

Results

Collective induction analysis. There is direct evidence for groups outperforming individuals on the Jasper acquisition problem. Indeed, the results appear to suggest that the most complex elements of Jasper require the benefits of collective induction (eg., synergy, insights). Alternatively, the group learning setting may have resulted in better performance due to the presence of a strong leader as opposed to the synergistic interaction of two members. To test the primacy of collective induction in greater depth we compared dominant groups with shared groups using amount of talking as the defining criteria for dominance.¹² For the primary summary variable, results showed no difference between the dominant and shared group conditions on the pairwise comparisons. However, the pairwise comparisons shown in Figure 11 reveal results which begin to approach significance as dominant groups ($m = 76.79$) generate more overall problem elements than individuals ($m = 61.48$), ($t = 1.95, p = 0.06$) although shared groups failed to approach significance for this difference.

Looking at plan feasibility constraints, as shown in Figure 12, found no significant effects except for payload solved. Results revealed that a higher percentage of dominant groups ($m = 75\%$) solve for the payload constraint when compared to individuals ($m =$

¹² For this design perspective, dominant or shared type of groups are determined by the amount of words spoken by a team member or by subjective observation of raters meaning. A dominant group is determined if one member generates more than or equal to 66% of the total words in the team's transcript; whereas, the classification is a shared group if neither member generates more than or equal to 66% of the total words in the team transcript. Secondary criteria for borderline cases consisted of using subjective ratings of the video observation data to assess assignment of teams in either of the two categories.

25%), ($X^2 = 4.50, p = 0.03$). Although shared groups were somewhat better than individuals, these differences were not significant.

For the optimizing elements, as shown in Figure 13, dominant groups ($m = 87.5\%$) were more likely to solve for multiple rescue routes than individuals ($m = 32.1\%$), ($X^2 = 4.61, p = 0.03$). However, observation of the figure indicates that for the remainder of the optimizing elements, the pairwise comparisons between groups and individuals do not appear to be consistent although there are no other significant differences. These findings suggest that dominant groups tended to account for the group versus individual differences when dominance is defined by the amount of talking between group members. Therein, some of the benefits incurring from a leader-based group may help a team in solving the more complex problem space elements.

Supplemental analysis. One of the interesting findings for Cluster 2, statement analysis, provides some clarification on why dominant groups do better than individuals. Dominant groups ($m = 35.66$) produced more metacognitive monitoring statements than individuals ($m = 26.17$), ($t = 3.01, p = 0.005$). This suggests that although a group is classified as dominant, it does not mean they fail to engage in collective induction.

The Cluster 3 measure, time on task, provides corroborative evidence regarding collective induction and shows how dominant groups vary directly from shared groups. One comparison which approached significance showed dominant groups ($m = 47.75$) spent more time completing the Jasper problem than shared groups ($m = 36.33$), ($t = 2.081, p = 0.06$). One can interpret this as a disadvantage, all things held equal. This suggests that groups that share and inductively generate without a leader come upon the solution much quicker than dominant groups, although their summary variables do not differ significantly. Another comparison approaching significance found that dominant groups ($m = 18.88$) recorded more initiatives than shared groups ($m = 15.40$), ($t = 1.88, p = 0.09$). Dominant groups may spend more time on Jasper because they are exploring the macrocontext more in search of features not remembered.

A new criteria for collective induction. After comparing results of dominant and

shared groups by using the traditional criteria for defining dominant/shared interaction, an alternative criterion of collective induction was tested. This reexamination of results involved changing the traditional criteria for identifying dominant or groups (ie., amount of talking or taking charge of a situation based on judgment of a video) into one which is more directly connected with collective induction. Since we have collected cognitive attributes of the group process it would be interesting to see if dominant groups, based on cognitive contributions, would result in meaningful changes in the findings. This premise was based on the notion that for the traditional measure one member of a group could be classified as passive if they spoke less than 1/3 of the time. Yet, many 'passive' members may contribute key insights to help solve Jasper. Therein, this new criteria was implemented to differentiate collective induction by classifying groups into those which had: a) a dominant member contributing the ideas or b) a shared exchange of ideas between the members. Thus, collective induction may now be determined by the extent of cognitive activity rather than gross talking activity.

In this case, a dominant group was distinguished from a shared group solely on the basis of the % of goals generated in their transcripts as encoded in their post hoc statement analysis. Groups were designated as dominant groups if they had one member who contributed 2/3 or more of the total goal statements assessed. Groups were designated as shared groups if neither one of the members contributed 2/3 or more of the total goal statements assessed (i.e. each member equally shared in the generation of goals). Use of this criteria resulted in about a 30% exchange in the membership of dominant and shared groups, from the traditional to the new criterion. As a consequence, much of the results obtained for pairwise comparisons were replicated; however there are some comparisons which were significantly different.

Using the new criteria revealed several insights. The most important change shown in Figure 14 revealed that a higher percentage of shared groups ($m = 83.3\%$) solve for the multiple routes problem space element when compared to individuals ($m = 32.1\%$), ($X^2 = 3.86, p = 0.05$) and to pseudo-groups ($m = 21.4\%$), ($X^2 = 3.66, p = 0.05$). This clearly

was not significant when the traditional criteria was used. In fact, visually comparing Figure 13 and 14 shows a change in direction across the two criteria. For the talker-based dominant groups, 87.5% considered the multiple routes optimizing element which then reduced to 75% for cognitive-based dominant groups. However, for talker-based shared groups, 63% considered multiple routes which then increased to 83.3% for cognitive-based dominant groups. This suggests that the sharing of cognitive ideas, rather than just the sharing of talking activities, contributes to performance in a way that results in superior problem solving efforts beyond what an individual could do alone.

Another important comparison which indicated the new classification is more authentic for describing collective induction is that shared groups ($m = 38.03$) produced more metacognitive monitoring statements than individuals ($m = 26.17$), ($t = 3.24, p = 0.003$) and pseudo-groups ($m = 26.00$), ($t = 2.93, p = 0.009$) which was not the case while using the traditional criterion. More importantly, the new significant comparison obtained using the cognitive contributions criterion revealed that shared groups ($m = 38.03$) produced more of these metacognitive monitoring statements than dominant groups ($m = 31.76$), ($t = 2.14, p = 0.05$).

The performance measures, time on task and number of initiatives, showed no differences between the different criteria of collective induction. Pairwise comparisons for time on task, showed significant differences when using the amount of talking criterion. This is in direct contrast to the cognitive contributions criterion which showed that dominant groups spent no more time on the task in comparison with shared groups ($p = .71$). All things considered, this leads one to believe that the variance between dominant versus shared groups is much less for talking than for cognitive contributions. Shared groups defined by cognitive contributions are more likely to demonstrate collective induction than those defined by amount of talking. Thus, using cognitive contributions to define collective induction levels are useful as they suggest alternative views of interpreting group productivity and cooperative learning studies. Just using amount of talking may be too narrow a focus to evaluate collective induction.

Discussion

The introduction chapter postulated that when a condition of shared interaction existed in the Jasper acquisition problem, subjects would inductively factor insights back into the group process resulting in a synergy which would not occur for groups containing a dominant member. Shared groups should provide levels of insights and a degree of synergy which provides learning, knowledge, and ideas unavailable without the benefit of a group. Yet, the interpretation of results indicate just a few differences between the shared and dominant groups. However, for the more complicated aspects of Jasper, dominant groups - not shared groups - yielded problem solving advantages over the individual conditions. There are two explanations in order.

First, although dominant groups have a dominant member and a more passive member, based on the amount of talking in their transcripts, this does not obviate collective induction. In fact, the passive member may contribute the most meaningful insights but not take many words to get their point across. This view is supported by the statement analysis which showed that dominant groups still generated more metacognitive statements than individuals. So collective induction occurs in these groups as well as the shared groups. Second, groups who were led by a leader may be beneficial for the more complex aspects of Jasper as they may encourage the group to get more involved in the macrocontext in their search across different elements of the problem net. However, we see that such a search can result in disadvantages for the talker-based dominant group as they spend significantly more time solving Jasper. Groups that share and inductively generate without a leader come upon the solution much quicker than dominant groups. Dominant groups may spend more time on Jasper because they are exploring the macrocontext more in search of features not remembered. Shared groups may utilize a distributed transactive memory (See Wegner, 1987) more than dominant groups who utilize access of the laserdisc for memory of specific problem attributes. Individuals, and dominant groups, gravitate towards transactions based more on the affordances supplied by the Jasper macrocontext, whereas shared groups tend towards transactions based more on affordances supplied by one another while using Jasper as a perceptual anchor. Each agent-environment transaction

supplies distinct advantages and creates a different pathway for problem solving, knowledge acquisition, and eventually transfer of knowledge from one situation to another.

Because 'talking' may not effectively distinguish collective induction in groups, we utilized a new criterion (cognitive contributions) to represent dominant versus shared interaction. Shared interaction on the most complex aspects of Jasper was significantly better than individuals when this criteria was used. Also, the cognitive-based shared group produced more metacognitive statements than the dominant group which directly indicates differences in group activity. We also see that the cognitive-based shared and dominant groups appear to be less like individuals as they fail to take as much time as individuals searching the Jasper macrocontext. The cognitive contributions criterion creates shared groups that distribute ideas not just surface-level talk.

Group leadership qualities defined by the new criterion, cognitive contributions, appear to be much more robust than qualities defined by the traditional criterion, amount of talking. This new criterion is decidedly useful as it resulted in alternative views of interpreting group productivity and cooperative learning. It makes the point that studies just using talking ability as the basis for leadership in groups may be severely limited and overstated, as leadership can result from cognitive contributions without much talking. We may say that what counts for success in collective induction is a function of the criteria which operationally defines dominance or shared activities.

Understanding the Effects of MetaCognition in the Jasper Acquisition Problem

Results

MetaCognitive activity type analysis. Our final stage of study was to go back and do an intensive analysis of metacognitive strategies present in groups and individuals as they establish mastery on Jasper. As mentioned, our statement analysis identified that one of the major differences between groups and individuals was the level of metacognitive activities present in their protocols. The intent of this portion of study was to classify both groups and individuals as to the particular type of metacognitive strategy which they

predominantly engaged in while solving Jasper. This would allow us to understand how specific types of metacognitive strategies might differ in their ability to help the group and facilitate collective induction.

Initially, subjects in the individual and the group condition were classified as either a 'problem planner', 'solution elaborator', or a 'meta-monitor' dependent on their protocol analysis encodings. The descriptors used to categorize each protocol statement are shown in Table 1. Upon review of this breakout, only 13% of all statements were encoded as problem planning statements. Unfortunately, this did not result in enough groups/individuals being classified as 'dominant problem planners' and as a result the analysis could not be performed using this stratification.

Consequently, a decision was made to utilize just two predominant metacognitive activity types: *elaborators* and *monitors*. If the group or individual's percentage of monitoring statements was equal to or exceeded 50% (ie, at least half of all their statements were classified by the protocol analysis as 'meta-monitoring'), then they were classified as monitors. Otherwise, they were classified as elaborators.

This dichotomy resulted in sufficient data points for metacognitive/cognitive activity type (elaborator or monitor) to be completely crossed with learning setting (group or individual) enabling a test of four conditions: group elaborators, group monitors, individual elaborators, and individual monitors. Because a thorough analysis of the learning setting has already been completed, only results which highlight a metacognitive/cognitive activity type main effect or a metacognitive/cognitive activity type x learning setting interaction are reported.

At the very top level of analyses we found that neither the main effect of metacognitive activity type, nor the metacognitive activity type x learning setting interaction, were significant for the primary variable in Cluster 1 or for the MANOVA performed on Cluster 3. However for Cluster 2, according to Hotelling-Lawly's criteria, we found that the main effect of metacognitive activity type approached significance ($F(5,34) = 2.45, p > 0.054$) but the metacognitive activity type x learning setting interaction failed to reach significance ($p > .52$).

Table. 1.--MetaCognitive Activity Type Descriptors Used in the Protocol Analysis
Encoding

Planning - What I want to do with information.

goal setting, problem identification, think ahead, recognition of insights,
what comes next, coordination of information, organizing subgoals,
stating assumptions or beliefs

Monitoring - What I have done wrong with information or how I evaluate what I am doing.

error detection, self-assessment, self-regulation, correction, arguments,
think-in-process, emotional affective, recognition of omissions,
misconceptions

Elaboration - What I do to amplify, expand, or refine information in solving the problem.

access of information, check-recheck of information, execution of a plan,
calculation, reminders, analogies, explanations, clarification, summarizing

The major consideration to be questioned was whether there were differences among group elaborators, group monitors, individual elaborators, and individual monitors. For the primary summative variable, % of problem space elements solved, results showed that two paired comparisons began to approach significance; Group Elaborators ($m = 81\%$) generated more overall problem elements than Individual Monitors ($m = 60\%$), ($t = 2.05$, $p = 0.053$) or Individual Elaborators ($m = 64\%$), ($t = 2.01$, $p = 0.06$). See Figure 15.

Analyzing at a more refined level, we see that there were no significant differences for constraints on plans among the four conditions. As shown in Figure 16, an evaluation of

the optimizing elements of the problem space revealed that a higher percentage of Group Monitors ($m = 87.5\%$) are significantly more likely to consider the multiple rescue routes than Individual Monitors ($m = 23.5\%$), ($X^2 = 4.61, p = 0.03$). Results approaching significance revealed a higher percentage of Group Elaborators ($m = 83.3\%$) are more likely to ($X^2 = 4.61, p = 0.03$). Results approaching significance revealed a higher percentage of compare times among plans than Individual Monitors ($m = 29.4\%$), ($X^2 = 2.97, p = 0.085$). These findings suggest that an individual monitor spends time monitoring at the expense of elaborating a solution to the problem. However, monitoring activities which naturally occur in the group facilitate solution of one of the more complex elements of Jasper. But, when we look at total % of problem space elements solved, we see a change. Group elaborators significantly out perform individual elaborators and individual monitors, yet the difference between group monitors and these individual conditions fails to reach significance. The remaining comparisons are better summarized under the Repsaj transfer problem as they can adeptly be compared to acquisition performance. Understanding whether different types of metacognitive activities differentially affect acquisition and transfer performance is one of the key issues in this portion of the study.

Discussion

Typically, metacognition is mentioned almost at an abstract level without differential assessment of the effectiveness of a particular strategy to affect CL and the transfer of knowledge. The Larson et. al. (1985) study first provided evidence of the differential effects for two types of metacognitive activity within a highly constrained and structured enactment of CL. Their findings showed that groups engaged in error monitoring were highly successful for acquisition performance in comparison with groups engaged in elaboration. However, on a subsequent group-to-individual transfer problem, the members who had participated in the elaboration group obtained a higher level of transfer performance. Our analysis is a direct follow-up to this study. As it turns out, our post hoc

classification of metacognitive strategies revealed the same predominant categories used in the Larson study. Consequently, their study sets up the prediction that group monitoring may be better than group elaboration for acquisition problems, but elaboration may be better than monitoring for transfer problems. This analysis evaluates that prediction but makes it more precise by seeing if metacognitive advantages/disadvantages are maintained or changed across group and individual learning settings.

Our acquisition results partially replicated the original Larkin et. al. study as they showed that group monitors and group elaborators did better than individuals for the most complex parts of Jasper; however only group elaborators address more problem elements in comparison to individuals. So, for the Larkin et. al. monitoring effect, it was replicated for the most complex problem elements when compared to individuals, but it was not better than group elaboration. The transfer results change for group monitoring but not for group elaboration.

Thus, by examining Larkin's original variables with greater precision, new findings have been distilled. It appears that although group monitoring helps in acquisition, these advantages diminish with transfer which is direct support for our original prediction.

This summarizes the primary findings for the Jasper acquisition problem, from the global-to- local levels, across learning setting, collective induction, and metacognition. The next section reports findings for the Repsaj transfer problem in the same global-to-local sequence.

Effects of Learning Setting-Collective Induction upon the Repsaj Transfer Problem

Jasper results clearly identify advantages for cooperative learning when compared to pseudo-groups and individual learning settings. Like many previous studies, this reinforces the idea that cooperative learning is a worthwhile endeavor. We showed that groups primarily engaged in metacognitive activities and secondarily explored the macrocontext, while individuals primarily explored the macrocontext and secondarily participated in metacognitive action. We also talked about the differences in dominant and

shared groups in terms of their distributed nature. Shared groups were more distributive but dominant groups showed tendencies to be more like individuals as they spent more time with the Jasper videodisc.

The major issue which remains is to see if these advantages for Jasper transfer to the near-term analogy problem (Repsaj) when individuals act alone. The first objective is to see whether participation in the cooperative learning setting facilitated continued success on the Repsaj problem. The second objective is to see whether the level of collective induction affected transfer on Repsaj. Finally, the third objective is to compare the dominant member and the passive member of the dominant group with each other and the individual learning setting to see if these conditions show different transfer abilities.

Results

Learning setting-collective induction analysis. At the very top level of analysis, we found no main effects of learning setting for any of our four clusters of dependent variables. An ANOVA was conducted on the % of problem elements solved and revealed no significant effects for learning setting or for any of the dominant - shared conditions. The first question asked is whether the group or individual setting a person experienced in Jasper facilitated their individual performance on Repsaj. The primary summative variable for transfer, % of problem elements transferred, indicated a significant difference between individual-to-individual and group-to-individual transfer, as shown in Figure 17. Individuals ($m = 84.3\%$) transferred more overall problem elements than members of Jasper groups ($m = 73.37\%$), ($t = 2.81, p = 0.0076$).

Pseudo-groups ($m = 82.63\%$) also transfer more problem elements than groups ($m = 73.37\%$), ($t = 2.30, p = 0.03$). Figure 18 also shows that individuals ($m = 84.3\%$) transferred more overall problem elements to Repsaj than members initially in shared groups ($m = 71.27$), ($t = 2.32, p = 0.027$).

Finally, Figure 19 shows results approaching significance. Individuals ($m = 84.3\%$) transferred more overall problem elements to Repsaj than passive members of dominant groups ($m = 73.53\%$), ($t = 2.01, p = 0.052$). This demonstrates that being a passive

member of a cooperate learning group may be worse than solving a problem as an individual. CL may not always lead to success for every member of the group when they encounter analogous types of ill-defined problems on their own.

Analyzing at a more refined level revealed that there were no differences between group-to-individual and individual-to-individual transfer for evaluating the feasibility of the plans they generated. Again, this is due to the high level of performance found within every condition. Looking at the optimizing elements of the problem space revealed one comparison approaching significance. As shown in Figure 20, people who were in Jasper groups appeared to be more likely to consider the multiple rescue routes in Repsaj than those who solved Jasper as individuals ($m = 10.7\%$), ($X^2 = 2.83, p = 0.09$). This was true for both shared and dominant groups although the finding only approaches significance levels.

Although a direct comparison of people who were in dominant versus shared teams yielded no significant differences in optimizing elements, two comparisons which contrasted these conditions to the individual learning setting were borderline cases as they started to approach significance. Refer to Figure 21. First, a higher percentage of members initially in dominant groups ($m = 35.7\%$) showed the trend to be more likely to consider the multiple rescue routes in Repsaj than those who solved Jasper as individuals ($m = 10.7\%$), ($X^2 = 2.68, p = 0.10$). Second, a higher percentage of members initially in shared groups ($m = 66.7\%$) showed the trend to be more likely to consider multiple vehicles in Repsaj than those who solved Jasper as individuals ($m = 28.6\%$), ($X^2 = 2.59, p = 0.10$).

Supplementary analyses. Analyzing Repsaj Cluster 2 measures identified distinct advantages for members initially in shared groups for Jasper. As shown in Figure 22, members in shared groups ($m = 10.22$) produced significantly more goal statements than those in dominant groups ($m = 8.14$), ($t = 2.42, p = 0.03$). Also, shared group members ($m = 26.88$) produced more % means statements than passive members of the dominant

group ($m = 21.15$), ($t = 2.31, p = 0.04$). Results approaching significance show that shared group members ($m = 26.88$) tend to produce more % means statements than dominant group members ($m = 22.95$), ($t = 1.81, p = 0.095$).

Alternatively, members initially in dominant groups ($m = 23.49$) for Jasper tend to generate more % states than members in shared groups ($m = 19.22$), ($t = 2.15, p = 0.053$), or even individuals ($m = 19.89$), ($t = 1.82, p = 0.078$) although these comparisons only show results approaching significance. Also, the passive members of the dominant group ($m = 23.80$) tend to produce more % states than individuals ($m = 19.89$), ($t = 1.82, p = 0.078$) although this comparison only approaches significance. There is tentative support here for the original hypothesis that shared groups actively generate more knowledge during acquisition which in turn helps transfer performance. Yet, one can see exactly where they benefit on Repsaj. They excel in the goal setting activities and in coming up with the means to produce the solution. In other words, individuals who were in shared groups show advantages on more problem solving-based activities working individually on Repsaj.

The single advantage (or perhaps disadvantage) for members in the dominant group was that these individuals produced more '% states' type of statements for the Repsaj problem space. This shows a strong necessity for maintaining the dominant group's initial orientation in Jasper. They dwell on details and search for facts at the exclusion of spending more time thinking about subgoaling, alternative solutions, or identifying the problem in different ways.

The passive members of these groups spent more time than individuals on Repsaj trying to find the facts perhaps to the point whereby they lose sight of actually solving the problem. In these situations, it may be worse for one to be in a group dominated by one person than it would to have acquired knowledge individually. This is an example that shows the affects of group process loss upon subsequent transfer activities for an individual. Hence, certain conditions of CL are not always healthy for helping a person to use their knowledge when they encounter similar problems in the future.

The Repsaj performance measures show that members initially in dominant groups

for Jasper spent more time completing Repsaj than any of the other conditions. For example, dominant group members ($m = 30.38$) spent more time completing the Repsaj problem than shared group members ($m = 22.67$), ($t = 2.50, p = 0.03$). Other comparisons approaching significance indicate that dominant members of the dominant group ($m = 33.75$) tend to spend more time completing the Repsaj problem than individuals ($m = 27.44$), ($t = 1.82, p = 0.078$) or passive members ($m = 27.00$), ($t = 1.99, p = 0.066$). This is a very salient contrast to some of the results which showed the dominant group faring so well on Jasper. Apparently, the dominant group member does not quickly access knowledge for use on Repsaj. Perhaps one hint is that these dominant individuals spend too much time stating the facts rather than subgoal/planning a solution. What transferred for the dominant group member was the propensity to be tied to the details of the problem. Thus, their tradeoffs between metacognitive actions and working in the context, although still producing transfer, may have hurt them overall.

Collective induction defined by cognitive contributions. When we summarize Repsaj findings by changing the traditional criteria for collective induction to the new criteria (ie., cognitive contributions), some different results ensue. One of the major changes observed was a trend which showed deficits accruing to the passive member of the dominant group. For example, while there were no significant results for the multiple pilots element when using the traditional criterion, the analysis using the new criterion revealed a higher percentage of individuals ($m = 53.6\%$) consider multiple pilots when compared to passive members of the dominant group ($m = 14.3\%$), ($X^2 = 3.98, p = 0.046$). Refer to Figure 23. This may indicate that when dominance is based on cognitive actions, the dominant member does not allow much collective induction to occur during Jasper as this person is supplying all the 'thinking activity'. By comparison, when dominance criteria is based on amount of talking it does not necessarily mean that the passive member is not thinking. This may be akin to what Brown, Collins, & Duguid (1989) refer to as 'cognitive apprenticeship'. However, when dominance criteria is based on cognitive contributions, it necessarily classifies the passive member as the one who

contributes less cognitively to the solution.

Another difference is that problem solvers who were in talker-based dominant groups generate fewer goals than those in cognitive-based dominant groups. People who dominate a group by talking profusively on Jasper have trouble when they have to generate their own goals on Jasper. However, this deficit does not occur for people involved in a dominant group based on thinking.

For Repsaj, dominant talkers generate more % state elements than shared groups or individuals but this fails to be true when we analyzed dominant thinkers. The interpretation posits that dominant talkers spend more of their time talking about obvious parts of problem (ie., the states) yet dominant thinkers are no different from shared groups on this measure.

Many of the changes emanating from dominant talker to dominant thinker are like the one just identified. That is, when amount of talking is the objective classifier, there are many pairwise comparisons which were either significant or approached significance. However, when the criteria was changed these differences do not appear except as cited. This is probably due to a qualitative change or increase in the stature of the dominant thinker group resulting in transfer of knowledge which is about equal to the shared group.

Discussion

The hypotheses one can make regarding transfer of knowledge are directly related to the two primary factors relayed in the Jasper discussion section. How is transfer affected by the cognitive benefits of having people work together? How is transfer affected by the benefits of actively acquiring knowledge within a highly perceptual-based macrocontext. For Jasper, we provided evidence that groups engage in collective induction and metacognitive strategies and generally approach the problem differently than individuals. Individuals were more inclined to focus on details and explore the macrocontext.

The original prediction put forth was that transfer performance -in general- would be quite good as the acquisition context (Jasper) affords perceptual learning. The experience of different problem features that induce learning activities (eg, 'generate sub-problems' or

'find data') would be recognized and then spontaneously accessed for Repsaj. However, this prediction assumed that groups and individuals would both maintain equal exploration of the context. The Jasper results clearly portrayed individuals (and to some extent dominant groups) as spending much more time exploring the macrocontext than shared groups. On the one hand, given the Jasper results, the expectation would be that individuals would transfer more than groups as they spent more time in the problem's perceptual context. On the other hand, the role of collective induction predicts that shared groups generate more knowledge, insights, and ideas beyond what a dominant group or individual could do, and thereby would transfer this 'cognitive benefit' to Repsaj.

The interesting results obtained for Repsaj found that each of these expectations turned out to be true for different aspects of transfer. This is one of the major contributions of this research. That is, transfer effects for the Repsaj problem space can be measured by two distinct components: a) transfer on the more complex parts of the problem and b) total transfer of problem elements (giving equal weight to each planning net element). Additionally, transfer can be elucidated to an even greater degree by looking at the other dependent measures assessed (eg., time on task). *Most studies only look at transfer for one particular unitary measure and fail to detect these differential aspects of transfer.*

We found that complex parts of Repsaj were solved better by people who participated in shared or dominant groups when compared to the individuals. Alternatively, for total transfer of elements, individuals did better than either group condition. Hence, groups appear to benefit from working together and exchanging metacognitive strategies which enhances problem solving on the hardest parts of Repsaj and individuals benefit from spending more time in the macrocontext which enhances the overall transfer of problem elements. Thus, each approach taken in Jasper by groups and individuals created differential return on investments, contingent on the specific components of transfer which are investigated.

Groups showed that even though their collective induction facilitated transfer for the more complex parts of Repsaj, their lack of exploration in the macrocontext left them unable to transfer those problem elements not accessed or sufficiently explored in the

videodisc. Groups may not explore the macrocontext as much as individuals due to their distributive nature. We said that in collective induction different members generate new ideas which are synergized in the group setting. Often, this results in identifying new problem directions or provides alternative solution paths for an ill-defined, complex problem. We also noted that groups may rely on each other for a kind of externalized transactive memory system (see Wegner, 1987), rather than searching through the Jasper videodisc for that information. Unfortunately this 'distributive intelligence' (see Pea, 1988) of groups, although facilitating more collective induction and metacognition, reduces a group member's amount of exposure in the context.

Another perspective on the distributive process of collective induction is that there is less necessity or responsibility for each team member to address every aspect of the problem. In other words, the workload is shared or stratified in accordance with the situational needs, roles, goals, and abilities of the group. One member may solve one component of a problem while another addresses a different component. McGrath (1990) refers to this as the tendency for groups to be partially nested and loosely coupled. Any member may construct different knowledge, which is then distributed to the other member as part of the solution outcome. Given an ill-defined, complex, multi-step problem like Jasper, such stratification of effort and responsibility is likely to occur. Concomitantly, when group members go on to solve similar type of problems as individuals, they only transfer the part(s) which they generated during acquisition. Other parts may have been generated by other members and since they were not constructed by that individual initially, or they may not have been shared in depth, they are not available to be transferred.

Although our research captured the distributive elements of collective induction in an optimal face-to-face setting, it is likely that other real world settings will not. If cooperative work or CL groups are not implemented in face-to-face settings but are geographically dispersed, or involved in asynchronous communication, (eg., distance education), then more problems may appear. The distributed aspects of knowledge may have detrimental effects if a person needs to use parts of knowledge which another person generated and now cannot retain access to that person or the information that person generated. With the

recent focus on groupware products and distributed computer networks as catalysts for disseminating learning environments, this is an issue which must not be taken lightly.

In contrast to groups, individuals do not have the luxury of relying on other members for knowledge, for memory of details, or to just localize their efforts for a particular component of the problem. They must generate everything on their own, take personal responsibility for every aspect of the entire problem, and use the macrocontext to access information/details of the problem. Indeed, the statement analysis clearly shows differing patterns of generative activity between groups and individuals.

The distributive/interdependent nature of group activities has theoretical and practical implications for CL and the transfer of knowledge. When the size of a learning group increases, collective induction possibilities may also increase as there would be greater distributive intelligence and more interdependencies among group members (up to a plateau and then process loss is activated). However, this decreases each group member's exploration and responsibility to the wholistic requirements of the problem. Taken to a full theoretical position, metacognitive activity in larger groups helps the group member do better (in acquisition and transfer) in coming up with answers for the complex parts of the problem but promotes less total transfer for any given group member. Dependent upon the diversity of measures within a given CL study, these reciprocating findings may be masked and results may not show the total picture to understand the complexities in evaluating success.

Looking at the Repsaj results at the final leaf level of comparison re-strengthens the thoughts already presented. The shared group member was shown to be the one most engaged in metacognition, and as a consequence, was deemed most indicative of collective induction and most distributive in nature. When compared with individuals, these members transferred much less overall. However, this finding was not reflected for dominant groups. We previously said that, in many cases, these groups were more similar to individuals with respect to exploring the macrocontext. Thus, the results imply that a dominant group, as determined by the amount of talking/observation, is much less distributive than a shared group. The implications are that the dominant group would

transfer more overall problem space elements than would be true for shared groups. This comparison however failed to reach significance. In reality, the dominant group explored the macrocontext less than individuals and generated less collective induction than shared groups. The multiplicative effect of these two factors weights this condition such that it results in a middle ground on transfer. The % problem elements transferred and statement analysis measures showed the dominant group to be more similar to the shared group but the performance variables indicate the dominant group is more similar to individuals.

Looking at the dominant group in depth uncovers another interesting pattern. For the % problem elements solved measure, the dominant member of the dominant group, seems to be similar to the individual, whereas the passive member is more similar to a shared group member. This is probably due to the passive member not being as actively involved in taking the lead in exploring Jasper and thereby not being able to generate as many problem elements on Repsaj as the dominant member. Yet, the passive members do not take as much time to solve Repsaj compared with the dominant members.

Comparison of the traditional with the new criterion of collective induction certifies their respective roles. Passive talkers still contributed some ideas and still shared in the inductive process even though they failed to talk as much as the dominant member. In contrast, the passive thinkers diminish the inductive process as they contribute very few ideas. This makes the cognitive-based dominant groups much more authentic than the talker-based dominant groups as the relationships between the passive and the dominant members show a much lower level of collective induction than is true for talker-based dominant groups.

Effects of Quality of Solution upon the Repsaj Transfer Problem

Results

Quality of solution analysis. In addition to evaluating dominant/shared interactions as a basis for working on Jasper, we subsequently went back and analyzed the data to see if a problem solver's original *quality of solution* affected their performance on Repsaj. The

analysis of quality of solution was an attempt to directly understand whether individual differences in problem solving ability affect transfer performance; and consequently become one of the underlying conditions of success in CL. We classified individuals, groups, and pseudo-groups into either above or below average categories based on their relative performance on the primary summative variable for Jasper. The first objective was to look at the issue of *quality of solution* as it affects transfer performance on Repsaj. Although the % of Repsaj problem elements solved measure shows a significant main effect for quality of solution ($F(1,55) = 15.60, p < 0.0002$), the primary summative variable for transfer, % of problem elements transferred, fails to reach significance ($p > 0.96$). This suggests that people who were above average for Jasper continue to be above average on the wholistic aspects of Repsaj. However, their total transfer of elements from Jasper is no different than those who were below average. Individual differences held across problems but these differences do not help in terms of the total transfer of elements. The interaction effect of quality of solution x learning setting was not significant for either measure. Also, according to Hotelling-Lawly's criteria, the MANOVA results showed there was an overall significant main effect of quality of solution for Cluster 4, recall recognition measures ($F(8,92) = 15.60, p < 0.04$) but the interaction effect failed to reach significance ($p > .82$).

As shown in Figure 24, for the % problem elements solved measure, the problem solvers initially classified as 'above average' for Jasper maintained their superior advantage over the 'below average' problem solvers for the Repsaj problem across all three learning settings: Above Average Group > Below Average Group ($t = 2.62, p = 0.02$), Above Average Individual > Below Average Individual ($t = 2.61, p = 0.015$), and Above Average Pseudo-Group > Below Average Pseudo-Group ($t = 2.48, p = 0.03$).

There were no significant effects for the feasibility constraints. However, a major finding from the pairwise comparisons showed above average groups do much better than below average individuals for consideration of the multiple vehicles element ($X^2 = 4.05, p = 0.04$) and this result is maintained for the multiple routes element ($X^2 = 4.08, p = 0.04$).

See Figure 25.

One interesting note on Cluster 4 measures is that quality of solution significantly impacts one's ability to perform on the multiple choice recognition task but does not necessarily help performance on the transfer of problem elements (on the whole). The above average problem solvers (as determined in Jasper) did much better on total recognition than below average problem solvers; Above Average Group > Below Average Group ($t = 2.63, p = 0.02$), Above Average Individual > Below Average Individual ($t = 2.16, p = 0.04$), but overall show no advantage for % problem elements transferred. This is highlighted because the dominant versus shared classification of cooperative learning produced differences in the direct transfer measure but not on the recognition memory task which infers that each of these views elicit different sensitivities in measuring the outcomes of learning.

One other finding regarding the % problem elements transferred measure is in order. Below average individuals transfer more overall problem elements than above (or below) average groups ($t = 2.37, p = 0.03$). This finding reinforces the collective induction findings where groups facilitate transfer of the more complex elements but individuals transfer more overall problem elements. However, it provides more specificity as the best groups cannot match the worst individuals for overall transfer. On the other hand, the best groups do much better on the multiple vehicle and multiple routes for Repsaj which involve simultaneous consideration of the complex, interrelated aspects of the problem space. Supplemental analyses failed to show any additional meaningful comparisons which were significant.

Discussion

We found, in general, that quality of solution made a significant difference and was a catalyst for facilitating transfer of knowledge. However there were no interactions with learning setting. Quality of solution has its greatest impact on transfer measures involving content or recognition of content rather than showing differences for total transfer, the type of statements, or performance measures. For the '% problem elements solved' measure,

the problem solvers initially classified as 'above average' on Jasper maintain their superior advantage over the 'below average' problem solvers for the Repsaj problem across all three learning settings. A major finding from the pairwise comparisons shows that above average groups do much better than below average individuals for the more complex problem elements (eg, multiple routes). In this sense, we see a similarity between groups encoded as 'above average' and groups previously encoded as 'shared interaction group', perhaps indicating that the level of collective induction is inherent in the best groups and shows up in their ability to solve the harder elements of Repsaj.

One interesting note on Cluster 4 measures is that quality of solution significantly impacts one's ability to perform on the multiple choice recognition task but does not necessarily help performance on the transfer of problem elements (on the whole). The above average problem solvers (as determined in Jasper) do much better on Repsaj recognition than the below average problem solvers, but overall show no advantage for % problem elements transferred. This is highlighted because the dominant versus shared classification produced differences in the direct transfer measure but not on the recognition memory task. Traditional measures used for CL research (ie., the multiple choice recognition task) are sensitive for capturing differences between above or below average teams for acquisition/transfer problems but quality of solution is an ineffective variable with respect to total transfer of problem elements. Because there is no interaction with learning setting, one presumes that if a problem solver performs above average during an initial learning setting, it may help that person remember items on a multiple choice memory test. Yet, it does not necessarily help in the use of knowledge, in comparison to below average problem solvers, for subsequent problem solving activities.

One other finding regarding the % problem elements transferred measure is the comparison which shows that below average individuals transfer more overall problem elements than above (or below) average groups. This finding is the flip side of shared groups appearing to have the same approach as the above average groups as here it appears that individuals (or dominant groups) seem to have the same approach as below average groups. This finding reinforces the discussion concerning the distributive nature of groups

facilitating the comprehension and use of knowledge for more complex aspects of the problem but reducing transfer on the total amount of problem elements. This comparison replicates that but at an even greater extreme as the best groups can not match the worst individuals at overall transfer. On the other hand, the best groups do much better on the multiple vehicle, multiple routes, and compare times measures for Repsaj; all of which involve simultaneous consideration of the complex, interrelated aspects of the problem space.

The comprehensive methodological framework utilized for this experimentation has proved to be invaluable for detecting differences between traditional and more seamless assessments of learning. If the recognition test was the only measure used, then the understanding of what counts for success would be particularly slanted and uni-dimensional. By provision of different transfer measures, alternative and more extensional views of success can be illustrated. Studies without multi-dimensional assessment techniques may not have a complete picture, and may in fact account for a predominant 'positive only' view of CL.

Effects of MetaCognition upon the Repsaj Transfer Problem

Results

MetaCognitive activity type analysis. For this part of the evaluation, the first objective was to see if monitoring strategies yield better problem solving on Repsaj than elaboration strategies, for each level of learning setting. The second objective was to see if this relationship changed (being an elaborator may be better than a monitor) from Jasper problem solving. An evaluation of the % problem elements solved variable showed no significant effects for metacognitive/cognitive activity type ($p > 0.11$) or the learning setting x metacognitive/cognitive activity type interaction ($p > 0.19$). Additionally no significant main or interaction effects were found for MANOVAs performed on the remaining three clusters of measures. However, the primary measure for transfer, % problem elements transferred from Jasper-to-Repsaj, reveals significant differences in the pairwise

comparisons.

Looking at the primary variable in more detail revealed Individual Elaborators ($m = 84.91$) transferred more overall elements than Group Monitors ($m = 71.12$), ($t = 3.14$, $p = 0.006$) and Group Elaborators ($m = 76.37$), ($t = 2.19$, $p = 0.045$). Furthermore, Individual Monitors ($m = 83.90$) transferred more overall elements than Group Monitors ($m = 71.12$), ($t = 2.10$, $p = 0.047$). See Figure 26.

There were no significant differences for the feasibility constraints of the Jasper problem space. Alternatively, for the multiple routes optimizing element, results showed that a higher percentage of the Group Elaborators ($m = 50\%$) considered multiple rescue routes when compared to Individual Monitors ($m = 6\%$), ($X^2 = 4.61$, $p = 0.03$). Please refer to Figure 27. Group monitoring appears to only enhance problem solving for complex parts of Jasper, but not for total elements solved, and the benefits do not transfer to Repsaj. This is also supported by the finding that, for the % problem elements transferred, individual elaborators actually did much better than group monitors. Thus, it appears that group monitoring strategies can actually result in a change in direction from acquisition to transfer problem solving. In contrast, group elaboration enhances total transfer and transfer of the complex elements on Repsaj. These results show that the metacognitive strategies for a given learning setting which are beneficial for Jasper acquisition performance may not necessarily hold true for Repsaj transfer performance.

Supplemental analyses of performance and recall variables found only two comparisons which approached significance. Individual elaborators ($m = 52.90$) tend to produce more words per minute on Repsaj than individual monitors ($m = 38.66$), ($t = 1.81$, $p = 0.08$). This finding was maintained from Jasper performance. Additionally, Individual Elaborators ($m = 10.36$) tend to take less time to complete the Repsaj recognition test than Individual Monitors ($m = 13.71$), ($t = 1.78$, $p = 0.086$). These analyses demonstrate a trend that elaboration and individual exploration of the Jasper macrocontext result in additional benefits for an individual solving a similar near term analogy problem.

Discussion

The discussion of metacognition for the Jasper problem identified two primary questions. First, would the predominant type of metacognitive activity (elaboration or monitoring) present in the learning setting condition (group or individual) differentially affect problem solver's performance on Jasper? Second, would the benefits of these relationships be maintained or changed for Repsaj? The Larkin et. al. study provided a benchmark for this type of testing. They found group monitors were better than group elaborators for an acquisition problem. But for a subsequent group-to-individual transfer problem, initial participation as group elaborators helped problem solvers more than if they had participated as monitors. An additional expectation is that groups should facilitate better monitoring than individuals, as individuals often commit conceptual or execution errors without realizing it. Being in the presence of a group may afford other members to monitor what one cannot 'see' for him/herself. The question is whether this would also be true for transfer performance. That is, would individuals who were group monitors for Jasper have superior performance for Repsaj when compared to individual monitors, individual elaborators, or group elaborators? Thus, we reasoned in our hypotheses that group monitoring would be the best condition in acquisition but elaboration activities should enhance transfer.

We replicated the Larkin findings to a degree but again found more subtle differences dependent on what component of transfer we were evaluating. For Jasper, our results clearly showed that group elaboration, like group monitoring, was better than individual conditions; but there were no differences between these conditions. Although group monitoring failed to enhance transfer, the group elaboration condition was found to be beneficial for Repsaj. We found two changes in direction from Jasper-to-Repsaj. First, the benefits of group monitoring (present for the complex parts of Jasper) wash out for Repsaj. These results are very similar to the Larkin study. Second, there was a complete change in direction for group monitors when we focus on the primary summative variables. Individual elaborators transferred more problem elements than group monitors. In summary, group elaboration proved to be superior for all components of

acquisition/transfer; whereas group monitoring was only superior for the complex aspects of Jasper and then failed to help problem solvers in Repsaj.

The group elaboration condition may provide a 'best of both worlds' effect. The statement analysis provided evidence that elaboration activities in Jasper generate outcomes. Without the outcomes, there may be a great difficulty to 'forward chain' Jasper-to-Repsaj transfer. As mentioned earlier, this connectivity across the problem may be a function of the amount of time spent exploring the macrocontext. Perhaps groups involved with monitoring failed to connect various subgoals with states, means, and outcomes in problem solving; thereby resulting in less overall transfer.

Although, individual monitors, don't appear to be as devastated in total transfer as group monitors, they do not fare well on different Repsaj measures. Results surrounding memory measures show that the recall test time was much quicker for individual elaborators than individual monitors. The ability to elaborate problem details, in comparison to self-monitoring, apparently yields an advantage in the ability to quickly access similar analogical elements on Repsaj. Because our research methods employed a more time stressed setting for Repsaj, the results suggest that individual elaborators may have advantages in transfer and memory performance due to superior problem solving efficiency. This was reinforced by the finding that individual monitors produce significantly more words per minute than individual (or group) monitors. Again this relates to being heavily problem-centered. These subjects appear to get immediately down to business, whereas the monitors search for what is wrong with the problem solving at the expense of connecting goals with outcomes, thereby resulting in the problem not being solved effectively.

One reason that the results showed similar yet different findings to the Larkin study is the nature of the types of problems people were solving. In the Larkin study, the implementation of cooperative learning was through the use of a more structured approach which involved well-defined problems. In contrast, the research reported used a naturalistic orientation within a highly perceptual macrocontext employing ill-defined problems. It may be that given this ill-defined context, the advantages of an elaboration

metacognitive activity caused the group to generate details focused around the perceptual anchor, and at the same time allowed them to consider new plans which generated a better solution. This shows up as advantages on both Jasper and Repsaj. In contrast, the effects of group elaboration in the Larkin study are masked because the problem is more well-defined and not in a perceptual context. When CL is implemented as a well-defined task without the possibility of exploring a perceptual context, monitoring may become more salient. In any case, neither study shows an advantage for the monitoring for transfer.

CHAPTER IV

SUMMARY OF DISCUSSION

The preeminent question which has guided the advancement of this research is "What are the advantages of cooperative learning in the Jasper Context?" This basic goal has been addressed in this paradigm to assuage some of the practical, methodological, and theoretical issues constraining the use of CL in research and in application. Each of the preceding sections have discussed results which pertain to this basic goal. In summary, we found differences in conditions of learning as subjects solved the Jasper and Repsaj problems.

The Jasper Acquisition Problem

Learning Setting

For Jasper, the group setting clearly performed better than the individual setting for the primary variable. The group also demonstrated superior performance over individuals for Jasper's most complex aspects (eg., the optimizing elements of the problem space). For less complex aspects of Jasper (eg., mentioning the range constraints) there was no difference between learning settings. Using a pseudo-group control, we substantiated the same pattern of results as the group also performed better than the pseudo-group, thus suggesting that there is a role for collective induction in cooperative learning settings.

Our supplemental analyses of learning setting first showed divergent activities for groups and individuals. We found that groups focus on generating goals, identifying problems, and metacognitive activities which relate to strategies for assimilating the problem; whereas, individuals focus on stating facts, defining procedures, and calculating solutions which relate strictly to the problem at hand. Additional analysis showed how much each learning setting accessed and searched the Jasper videodisc. Individuals (and

also pseudo-groups) activated the videodisc much more frequently than groups. These supplemental analyses reinforce the point that groups primarily engaged in metacognitive activities and secondarily explored the macrocontext, while individuals primarily explored the macrocontext and secondarily participated in metacognitive strategies. This remains a key insight for the interpretation of the transfer results.

Collective Induction

The results for learning setting suggest that solving the most complex elements of Jasper require the benefits of collective induction (eg., synergy, insights). Alternatively, the group may have obtained better performance due to the presence of a strong leader as opposed to the synergistic interaction of two members. Direct comparison of dominant versus shared groups showed no differences between these conditions. However, these findings suggested that dominant groups tend to account for the group versus individual differences if dominance is defined by the amount of talking between group members. Therein, some of the benefits incurring from a leader-based group may help a team in solving the more complex problem space elements.

The supplemental analyses for goal statements and performance measures provided clarification on why dominant groups did better than individuals. Dominant groups generated significantly more metacognitive statements than individuals. This suggested that although a group is classified as dominant, it does not mean they fail to engage in collective induction. The dominant group may exchange cognitive benefits from the dominant talker to the more passive member in a manner similar to the way shared groups share these benefits. However, additional knowledge about dominant groups, as obtained by looking at the time on task measure, reveals that this dominant-to-passive arrangement for collective induction may have some costs. The dominant group spent more time completing Jasper in comparison to the shared group. This suggests that CL groups that share and inductively generate without a leader come upon the solution much quicker than dominant groups. It appears that dominant groups (whose leaders are determined by the amount of talking they engage in) focus more on retrieval of information from the Jasper macrocontext which

results in them spending more time on the problem. In fact, the results showed dominant groups accessed the videodisc much more than shared groups. They may spend more time on Jasper because they are exploring the macrocontext in search of features not remembered; whereas shared groups may not need to spend as much time accessing scenes from the video. Thereby, they solve Jasper quicker than their counterparts.

An alternative measure of collective induction. After comparing results of dominant and shared groups by using the traditional 'talking' criteria for defining dominance/shared interaction, an alternative criterion of dominance/leadership was tested. Results revealed several insights when the criteria was changed to reflect dominant/shared interaction on the basis of '*cognitive contributions*'. Another key finding was that the cognitive-based shared group did significantly better than individuals on the 'multiple routes' problem. The sharing of cognitive ideas, rather than just the sharing of talking activities, contributes to performance in a way that results in superior problem solving beyond what an individual could do alone. Another important comparison which indicated the new criteria is more authentic for describing collective induction is that shared groups produced significantly more metacognitive statements compared to dominant groups.

This new criteria of collective induction portrays shared and dominant teams as being less like individuals and more distributive in nature. In contrast, results using the traditional criteria found that dominant teams were similar to individuals. This reinforced the idea that this innovative way to classify collective induction in CL is more reliable than just using the traditional amount of talking criteria.

MetaCognitive Strategies

In the learning setting section we found that one of the major differences between groups and individuals was the greater amount of metacognition present in the group setting, especially for shared groups based on the exchange of cognitive contributions. An alternative look at the data was undertaken to classify both groups and individuals as to the particular types of metacognitive strategy which they predominantly engaged in while solving Jasper. This allowed an understanding of how specific types of metacognitive

strategies might differ in their ability to help the group (or the individual) on Jasper and Repsaj. We discovered two predominate types of metacognitive strategies in group and individual conditions: solution elaboration and meta-monitoring. This resulted in crossing learning setting with each metacognitive activity type, thus allowing comparison of four conditions: group elaborators, group monitors, individual elaborators, and individual monitors.

Results showed that none of the learning setting x metacognitive activity type interactions were significant although the metacognitive activity type variable was significant for the statement analysis. Comparisons among the four conditions revealed that group elaborators generated more overall problem elements than individual monitors or individual elaborators, yet the difference between group monitors and these individual conditions failed to reach significance. At a more refined level, we see that there were no significant differences for constraints on plans among the four conditions. An evaluation of the optimizing elements revealed that group monitors are significantly more likely to consider the multiple rescue routes than individual monitors and that group elaborators are more likely to compare times among plans than individual monitors. *This finding suggests* that an individual monitor spends time monitoring at the expense of elaborating a solution to the problem. Yet, monitoring activities which naturally occur in the group facilitate solution of one of the more complex elements of Jasper. The remainder of comparisons are better summarized under the Repsaj transfer problem section where they can adeptly be compared to acquisition performance. This summarizes the primary findings for the Jasper acquisition problem from the very global level down to the very local level across learning setting, collective induction, and metacognition. The section now moves on to summarize findings for the Repsaj transfer problem in the same global to local sequence.

The Repsaj Transfer Problem

Learning Setting and Collective Induction

The interpretation of transfer results must be indexed back to acquisition results. In

Jasper, groups primarily engaged in metacognitive activities and secondarily explored the macrocontext, while individuals primarily explored the macrocontext and secondarily participated in metacognitive action. Interpretation also must include the finding that for Jasper, groups performed significantly better than individuals or pseudo-groups. We also talked about the differences in dominant and shared groups, when collective induction is based on amount of talking. These results indicated that shared groups were more distributive but dominant groups showed tendencies to be more like individuals as they were less distributive.

What does this mean for transfer performance? Group-to-individual transfer conditions were compared with individual-to-individual transfer to assess the advantages or disadvantages of learning setting for Repsaj. Different types of transfer were discovered between groups and individuals dependent on whether the focus is total amount of elements transferred or on the most complex aspects of the problem. The primary summary variable for Repsaj, % of problem elements transferred, showed a significant difference between group-to-individual and individual-to-individual transfer. Individuals (as well as pseudo-groups) transferred more overall problem elements than groups. There were no differences between group-to-individual and individual-to-individual transfer for evaluating the feasibility of the plans they generated. Yet, for the optimizing elements of the problem space, people who were in Jasper groups (either dominant or shared) were significantly more likely to consider the multiple rescue routes in Repsaj compared to individuals (and pseudo-groups although this finding barely approached significance).

Supplemental analyses identified distinct advantages for shared group members. They generated more goals (and more means) than individuals who were members of a dominant group. Alternatively, people who were in dominant groups for Jasper generated more facts (states) than individuals who were in shared groups, or even individuals. Passive members of these dominant groups also produced more facts than individuals do. This showed a strong propensity for maintaining the dominant group's initial orientation on Jasper for dwelling in the details and searching for facts at the exclusion of spending more

time thinking about subgoaling, alternative solutions, or identifying the problem in different ways.

The Repsaj performance measures showed that people who were in dominant groups spent more time completing Repsaj compared to the other conditions. This shows a deficit in performance when compared with shared groups and individuals. Even more interesting, the dominant member of the dominant group spends more time than the passive member of the dominant group on Repsaj. This is a very salient contrast to some of the results which show the dominant group faring so well on Jasper.

Repsaj results which use cognitive contributions to rate collective induction, found differences from the more traditional criterion. One of the major changes observed was a trend which showed deficits accruing to the passive member of the dominant group. For example, a higher percent of individuals arrive at the multiple pilots optimization when compared to passive members. Another difference was that dominate group members (defined by talking activity) generate fewer goals than do dominant members (defined by cognitive contributions). People who dominate a group by talking profusively on Jasper have trouble when they have to generate their own goals on Jasper. However, this deficit does not occur for people involved in a dominant group defined by their cognitive contributions. Consequently, the new criterion is still effective for assessing components of the Repsaj transfer problem which would not have been significant using the traditional measure.

Learning Setting and Quality of Solution

In addition to evaluating dominant/shared interactions as a basis for working on Jasper, we subsequently went back and analyzed the data to see if an individual's or a group's original quality of solution affected their performance on Repsaj. The analysis of quality of solution was an attempt to directly understand whether individual differences in problem solving ability affect transfer performance; and consequently become one of the underlying conditions of success CL. We classified individuals, groups, and pseudo-groups into either above or below average categories based on their relative performance on

the primary summative variable for Jasper. We found, that quality of solution made a significant difference and was a catalyst for facilitating transfer of knowledge. However there were no interactions with learning setting. For the % problem elements solved measure, the problem solvers initially classified as 'above average' on Jasper maintained their superior advantage over the 'below average' problem solvers for the Repsaj problem across all three learning settings. A major finding from the pairwise comparisons showed that above average groups do much better than below average individuals for the more complex problem elements (eg., multiple routes).

One interesting note on Cluster 4 measures is that quality of solution significantly impacts one's ability to perform on the multiple choice recognition task but does not necessarily help performance on the transfer of problem elements (on the whole). The above average problem solvers (as determined in Jasper) did much better on Repsaj recognition than the below average problem solvers, but overall showed no advantage for % problem elements transferred. This is highlighted because the dominant versus shared classification of cooperative learning produced differences in the direct transfer measure but not on the recognition memory task which infers that each of these views elicit different sensitivities in measuring the outcomes of learning.

One other finding regarding the % problem elements transferred measure is in order. Below average individuals transfer more overall problem elements than above (or below) average groups. This finding reinforces the collective induction findings where groups facilitate transfer of the more complex elements but individuals transfer more overall problem elements. On the other hand, the best groups do much better on the multiple vehicle, multiple routes, and compare times measures for Repsaj; all of which involve simultaneous consideration of the complex, interrelated aspects of the problem space.

Learning Setting and MetaCognition

The objective of the final part of the evaluation was to see - for individual and group learning settings - if monitoring strategies yielded better problem solving on Jasper than elaboration strategies, and then to see if this relationship changed for Repsaj problem

solving. Results showed that group elaboration strategies prevailed as the best condition for acquisition and transfer. An evaluation of our primary summative variable for Jasper showed that group elaborators clearly out performed individual elaborators and individual monitors but not group monitors. For Repsaj, this finding partially changed as people who were group elaborators on Jasper did not do as well as individual elaborators and showed no significant differences from either individual or group monitors.

Alternatively, for the multiple routes optimizing element, results showed that people who were group monitors on Jasper did much better than those who were individual monitors; whereas group monitors did no better than either individual monitors/elaborators for Repsaj. However, people who were group elaborators on Jasper clearly did better than those who were individual monitors for this complex element. Group monitoring appears to only enhance problem solving for complex parts of Jasper but not for total elements solved and the benefits do not transfer to Repsaj. This is also supported by the finding that, for the % problem elements transferred, individual elaborators did much better than group monitors. Thus, it appears that group monitoring strategies can actually result in a *change in direction from acquisition to transfer* problem solving. In contrast, elaboration enhances total transfer and transfer of the complex elements on Repsaj. These results show that the metacognitive strategies for a given learning setting which are beneficial for Jasper acquisition performance may not necessarily hold true for Repsaj transfer performance.

Supplemental analyses revealed that individual elaborators produced more words per minute on Repsaj than either individual monitors or group monitors. This finding was maintained from Jasper performance. Additional analyses on recall test time showed that individual elaborators were much quicker than individual monitors.

This concludes a summarization of results obtained for the Repsaj transfer problem which have looked at learning setting, collective induction, quality of solution, and metacognitive strategies. The final concluding section acts to integrate these results with more broadly defined theoretical models of transfer.

CHAPTER V

CONCLUDING REMARKS/ FUTURE DIRECTIONS

Cooperative Learning may be studied under a myriad of circumstances and situations. The experimental design perspectives undertaken for this research paradigm have focused on understanding the knowledge acquisition-access process. The necessities of the social construction of knowledge (Bereiter & Scardamalia, 1989) involving a situated context, perceptual learning, generative learning, collective induction, and metacognition have been established. There are multiple tradeoffs occurring when these factors are simultaneously present in a learning situation. Indeed, the research has helped us to understand whether "many hands make light work" or "too many cooks spoil the broth" is the appropriate adage to metaphorically apply to learning.

The interpretation of results must be indexed to the idea of what it means to cooperate. This research has explicitly chosen an implementation of CL which centers on the naturally occurring opportunities for people to work together in everyday problem solving situations rather than a more structured approach to CL. Other enactments of CL may produce different results. The research plan allowed groups to be flexible in addressing the Jasper problem and may have opened the door for group process loss to occur (eg., another member may provide interference rather than an inductive affect for the team). The effects of process loss may be an alternative way to view the data as groups transferred less overall elements than individuals. In this case, the members may coexist in the same problem space but fail to distribute their intelligence in a way that results in meaningful transfer on Repsaj. With the advent of a more structured reciprocal learning and role stratification, additional involvement with the macrocontext might have been accomplished. The point to be made is that different forms of collaboration are possible which have ramifications for

varying levels of transfer. This research provides insights for a particular form but the door remains open to investigate additional perspectives in cooperative learning.

Our perspective provides support for a more contextualized basis for understanding problem solving in groups and is thereby conceptually related to positions taken in situated cognition (see Brown, Collins, & Duguid, 1989; Clancey & Roschelle, in press; Greeno, Smith, & Moore, in press), everyday problem solving in culture (Lave, 1988, Meacham & Emont, 1989; Rogoff & Lave, 1984, Sinnott, 1989), cognitive apprenticeship (Collins, Brown, & Newman, 1989; Palincsar & Brown, 1984; Rogoff, 1990), naturalistic decision making (Klein, 1989; Rasmussen & Pejtersen, in review), and ecological psychology (Gibson, 1979/1986; Shaw, Turvey, & Mace, 1982). Theoretically, it supports a position that meaning can be generated 'on the fly' in a situated context, and is relative to the generation or construction of knowledge. Knowledge acquisition-access in problem solving is highly related to acting upon and sharing affordances inherent in the problem solving environment. The research conducted supports Greeno, Smith & Moore's position on transfer in situated learning -in part- but extends it by elucidating a variety of conditions within cooperative learning which precede transfer, or lack thereof. Greeno, Smith, & Moore indicate:

For activity learned in one situation [Jasper] to transfer to another situation [Repsaj], the second situation has to afford that activity and the agent has to perceive the affordance. In many cases, a situation affords several different kinds of interaction that are all regarded as successful performance. If the situation is changed, some of those interactions can still occur and others cannot, that is, the structure of some, but not all, versions of the initial activity are invariant across the transformation of the situation. If a learned activity is to transfer, then, it has to be learned in a form that is invariant across changes in the situation or that can be transformed as needed, and transfer depends as well on ability to perceive the affordances for the activity that are in the changed situation. . . . The range of situations that provide affordances for an activity constitutes an important aspect of the socially constructed meanings of the properties of those situations, so that the potential for transfer between situations is shaped by the social practices in which people learn the activities. (Greeno, Smith, & Moore, in press, pp. 4, 6)

The presence of collective induction in a learning setting resulted in team members acting upon different affordances for the collective success of the group. In fact, the social practices in problem solving were shown to change from shared-to-dominant based

interaction teams. This was manifest in terms of solving the complex parts of the Jasper problem. Each member constructed meaning in accordance with a particular component of the problem and each member was responsible for or 'picked up' on that part of the problem. Members collaborated by sharing these affordances/effectivities for a particularly complex part of Jasper in order to produce a solution. In this case, a transactive system was formed wherein differentiated responsibility and distributed knowledge were generated across members. In fact, members even used each other as external memory systems, as opposed to working with the videodisc, in order to save time. Such a situation makes members very interdependent upon each other to act on a final solution. Upon review of transfer performance, those members which relied upon another team member to construct knowledge as an action in support of a given affordance, did not notice as much information in the Jasper context and their total transfer performance on Repsaj suffered.

Individuals, who are responsible for generating all the knowledge and must deal with all the affordances for themselves, did much better on Repsaj for the total amount of transfer elements as they could see the invariance from Jasper-to-Repsaj as they noticed more of the affordances and were heavily entrenched in the perceptual context to begin with. Yet, the tradeoff was that collective induction groups attuned themselves to the more ideational, creative aspects of Jasper and used their collective abilities to solve this part of the problem. In turn this helped them on the associated Repsaj affordances. Hence, shared group members recognized the invariant aspects of the complex parts of Repsaj as they had participated in the generation of these for Jasper, but individuals without the advantage of collective induction failed to obtain these elements on Repsaj.

This is an example of how the research has explicated some of the more general aspects of the Greeno, Smith, & Moore view of transfer into specific tests of conditions underlying acquisition and transfer performance.

Analogical transfer in situated, cooperative learning does not appear to purely be a function of schema-based memory but is a direct consequence of generative learning between an individual(s) and what the world has to offer at a given point in time. Whether

meaning is constructed through collaboration with other people or by recognizing changes in our own perception in a situation, or an interaction thereof, there is a transactive quality of naturalistic learning which must be held in contrast to pre-structured views of learning that focus on representations to be retrieved or stored in memory. Approaches typically taken in the structured mapping literature relate knowledge transfer with symbolic cognitive processes or representations (See Gentner, 1983; Gick & Holyoak, 1980, 1983; Ross, 1987).

Cooperative learning has been shown to be the result of problem solver-macrocontext interactions. Our model of situated, cooperative learning focuses on the reciprocation between the abilities a person brings to the problem and the attributes of the environment which afford these various abilities as actions. The roles of learning setting, perceptual learning, dominant or shared interaction, quality of solution, and metacognitive strategies are prime components in what Brown & Campione (1991) refer to as an active "community of learners". The importance of the social construction of knowledge in real world contexts is the basis for acquiring knowledge and affording transfer across situations.

Finally, I would like to suggest ten characteristics which summarize a real world approach to situated, cooperative learning (adapted from Young & McNeese, in review) which are strongly coupled to this research as theoretical constructs and as such are trajectories for future research:

1. Real world cooperative learning requires the coordination of multiple cognitive processes, applied through multiple paths (Siegler & Jenkins, 1989). Examples include analysis, planning, problem identification, metacognitive monitoring, and problem solving while comparing multiple solutions to multiple subproblems.
2. Real world cooperative learning occurs within complex contexts that provide critical perceptual cues and rich situational affordances (Rogoff & Lave, 1984); for example, the information, dialogue, technology, and atmosphere of an operating room.
3. Real world cooperative learning is interpersonal. Greeno, Smith, & Moore (in press) write, "The issue of [problem solving] is social in a fundamental way. Learning occurs as people engage in activities, and the meanings and significance of objects and information in the situation derive from their roles in the activities that people are engaged in. (p.2)".
4. Being interpersonal, real world cooperative learning requires the social

construction of knowledge (Bereiter & Scardamalia, 1989; Edwards & Middleton, 1986). More than simply communicating or coordinating within a group, problem solving requires that the group members construct a shared perception of the problem and the solution, often mediated by technology.

5. Real world cooperative learning is often ill-structured and requires generation of relevant subproblems (Cognition and Technology Group at Vanderbilt, 1992). Despite careful and extended planning, real situations vary widely from case to case, and require continuous identification of problems, sub-problems to these problems, and solutions. When complex problem solving is done on the fly, problems that are detected must be conceptualized into manageable subproblems that afford specific actions: planning is integrated throughout the problem solving process.

6. Real world cooperative learning involves the integration of distributed information, typically from various specialties and domains. For example, solving the problem of a successful combat mission involves intelligence information, piloting skills, weather information, and appropriate weapon selection and use, etc.

7. Real world cooperative learning takes place across extended time frames. Such problems cannot be solved in a few minutes or even in a few hours, and are often completely beyond the time and space constraints of a single individual. They have a developmental history and future all contextualized in the ongoing situation.

8. Real world cooperative learning involves several possible competing solutions (Meacham & Emont, 1989). Rather than a single correct solution, most real world problems encountered in cooperative learning have multiple correct solutions as well as "almost workable" solutions. Alternatives must inevitably be planned, worked out in detail, compared, and subsequently selected or rejected (see Kugler, Shaw, Vicente, & Kinsella-Shaw, 1991, for a topical description of multiple goal paths).

9. Real world cooperative learning involves discovering problems and noticing perceptual attributes of the problem, such as detecting relevant from irrelevant information (Bransford, Sherwood, Vye, & Rieser, 1986). Problem detection and noticing that a problem affords a particular action or solution is a critical component of the cooperative learning problem solving process often missed in traditional training, education, human factors, or artificial intelligence domains. When simplified well-defined problems are substituted for realistic problems, students are denied an opportunity to acquire and practice this important perceptual skill.

10. Finally, real world cooperative learning involves inherent values, intentions, and goals that often have personal and social significance (Johnson, Moen, & Thompson, 1988). More specifically, value issues may arise surrounding the implications of personal error and cooperative problem solvers may be aware of these issues during the course of their activities.

When problem solvers acquire 'knowledge as problems' by experiencing these characteristics in a real world context, the subsequent transfer of knowledge is enhanced.

The Jasper macrocontext is indicative of a successful constrained naturalistic domain which incorporates these characteristics without the necessity of having a highly structured, highly trained implementation of CL (eg., Dansereau's MURDER paradigm); and as such has now been shown equal to the task of enabling a community of learners.

On a final perspective, one continuing goal to be upheld is the transition of our results as a basis for the design of computer-supported cooperative learning environments and intelligent tutoring tools. For example, our results suggest that future developments need to insure that CL groups (who share collective inductions equally and engage in metacognitive actions) are directed to perceptually learn by being exposed more to the situated context. Our results show that these groups tradeoff perceptual learning for collective induction and metacognitive strategies. Such a support system might overcome some of the losses we identified as being associated with distributive, transactive groups. Concomitantly, when individuals are involved in situated problem solving they need to be provided with an environment which allows them to engage in more metacognitive strategies and encounter the multiple perspectives of others. These two examples reveal specific areas where scaffolding effects would help both groups and individuals albeit in entirely opposite ways. In this case, we have used research to define some of the inadequacies in individual and cooperative learning and this may be the basis for proposing new learning systems which invite additional thinking, problem solving, and transfer.

Hence, an enabling of students to go beyond the traditional boundaries of 'educational bureaucracy' and to discover new forms of situated cognitive apprenticeship (Collins, Brown, Newman, 1989) have been achieved; wherein people, machines, design artifacts, culture, environments, and other objects or agents engage in meaningful transactions to establish a 'distributive intelligence' (Pea, 1988). What the learning context can afford and what the individuals in that context can effect will ultimately determine the nature of cooperative problem solving, and consequently, the transfer of knowledge to another context for ones future endeavors.

APPENDIX A
EXPERIMENTAL MATERIALS

The Repsaj Problem Text

It is 0800 hours in western hemisphere somewhere over Western Canada. Debra Mason has recently been commissioned as a Second Lieutenant in the 58th Air Force Aero Squadron and is stationed at Fitts Field located about 200 miles northeast of Regina, Saskatchewan. Lt. Mason, Lt. Valery Lee, and Capt. Grady O'Toole have just finished their aerobics run/weigh-in to evaluate their physical conditioning. The requirements state that each officer must complete a two mile run on Route 814 (a highway which connects Fitts Field with the Raybolt Depot). The three officers are comparing their results. Lt. Mason laments (while looking at a speed limit sign), "Well I don't feel like I ran at 60 MPH but I did OK. I ran it in under 10 minutes and weighed in at 110 lbs." Capt. O'Toole bemoans: "Well you are lucky and young - It took me 14 minutes and I weighed in at 110 lbs more than you. I guess that puts me on the fatboy program. Lt. Lee chimes in: "well I weighed in at 120 lbs less than you Grady." Lt. Mason cuts the conversation short as she realizes she has a final review seminar on Snowhawk operations to attend shortly. She showers and now enters Lt. Col. Elton Learnad's classroom.

Lt. Col. Learnad has just begun a mission debriefing to summarize the operational capabilities of the Snowhawk, a new type of flying snowmobile recently acquired by the squadron. The snowhawk looks like a long snowmobile with 30 ft. wingspan overhead. It has flying characteristics similar to a light airplane, except it can land and takeoff with runners (similar to those on a snowmobile), rather than landing wheels, if there is a minimum of 3" of snow on the ground. If there is no snow than it would

use its standard landing wheels. Its takeoff and landing operations are like an ordinary lightweight airplane. The Snowhawk is used in remote, snow covered areas which prove to be treacherous for other air vehicles. However, it has limited snowmobile capabilities due to its wing structure. It is only designed for limited ground movement such as needed for takeoff and landing operations.

Lt. Mason has received training on this aircraft for the last 5 months. She just completed her qualifying ride in the Snowhawk last week as all the pilots training in the Snowhawk program are required to land/takeoff in snow at the runway at Crocket's Pass. Lt. Mason now gives her undivided attention to the words being spoken by the Lt. Col.

.....The Snowhawk generates about 45 horsepower (typical for a snowmobile engine) and uses premium gas. You can always see how much fuel is left as it has a see through tank with calibrations for each gal on it. It's fuel tank holds 5 gals at a net weight of 50 lbs. Normally, when the winds are calm, for every 1.5 minutes of flight time the Snowhawk can cover 1 mile. Also, to land the beast you will need 120 yds. of field. Last night I flew the Snowhawk on a roundtrip to Rocksberg (about a total of 72 miles) and I used about 4 gals of fuel. Behind the pilot's seat there is a passenger's seat. Behind the passenger's seat there is a trunk area. Within the trunk there is a foldup stretcher for emergencies which alone weighs 15lbs. Typically, the craft will also keep a 1 gal. gas can in the trunk space. The Snowhawk can safely carry a maximum weight (i.e. its payload) of 290 lbs which includes weight of the fuel, the pilot, and any other items on board. This maximum must not be exceeded. Finally, you won't be able to lift the snowhawk by yourself, it weighs

300lbs. At this point, Lt. Col. Learnad suggests that the class end early today. Lt. Mason is happy as she is tired from the aerobics and later on that day she was scheduled to be on duty at the communications center.

As evening approached, most of the people at Fitts field readied themselves for a scheduled large-scale maneuver in areas far beyond the confines of Fitt's Field. Lt. Mason's role in this maneuver was to remain stationary and act as director of communications-command post at Fitts Field. She would be on-duty for the night shift. During this timeframe there were very few people around as most were involved in the maneuver. Lt. Mason is about to doze off at her desk (as it is nearing sunup) when she receives an alert on channel 21 of her ham radio.

"This is an emergency broadcast, code X4LF, transmitted from the Raybolt Fuel and Weapons Depot at 0500 hours. Do you read me?" Lt. Mason acknowledges the alert and then the voice continues....."Please stand by.....Attention, this is Sgt. Eddie Speaks requesting medical help for an injured officer participating in the maneuver. At 0450, I received a transmission from the remote Crockett's Pass area. Capt. Wanda Dixon has indicated that Second Lt. Valery Lee has contracted a case of frostbite and must not walk any further. Lt. Lee has indicated that she is experiencing numbness in her feet which she got wet. Capt. Dixon has administered some initial medical attention (she has removed Lt Lee's socks and shoes and has covered her feet) but the Lt. will need to be moved to a medical facility as soon as possible. They have no other means to warm Lt Lee's feet. She will need moved on a stretcher as any external force on her feet may cause severe swelling and damage. Fitts Field is the only area within 150 miles of

Crocket's Pass which may have treatment available." At this point Lt. Mason pulls out a map of the entire area and continues her conversation with Sgt. Speaks. Sgt. Speaks continues: "Lets see, you are at Fitts Field and I am at Raybolt Depot 72 miles east of you on Rt. 814. Capt. Dixon indicated there are no roads into the Crocket's Pass area and that it had taken them 6 hrs to march into Crocket's Pass from Raybolt Depot. There is a radio tower about 2 miles due south of Crocket's Pass which you can see at night. It looks like Crocket's Pass is 78 miles from Fitts Field by air. However, there is only about 1500 ft of runway there....Somehow we must quickly begin rescue operations to get Lt. Lee medical treatment. Can you help us down there? OK, I have another call I must attend to now. Thanks for your assistance."

As Sgt. Speaks relays information to Lt. Mason, the concern hits home as she remembers that Lt. Lee was her aerobics partner. Lt. Mason tries to put all the information together to decide how to respond to the emergency. She remembers that one of the first flights of the Snowhawk was to the field at Raybolt Depot. Another thing that comes to her mind is that after the aerobics run/weigh-in she was examined by Dr. Abra Matthews. The physician mentioned that he would be on call at the Fitts Infirmary in the event Lt. Mason wanted to confirm some of the post-aerobics tests. At this point, Lt. Mason calls Dr. Matthews wherein the following information is exchanged: "Yes, we would be able to treat Lt. Lee if you can get her here. I will be on this shift for another 6 hrs. Try to get her here as fast as possible so we can properly treat the frostbite and prevent further ramifications." Lt. Mason mulls over her thoughts..... "I can't get into Crocket's Pass by car or truck and a standard plane or helicopter would be too risky given heavy

snow conditions in the mountainous area. However, What about the Snowhawk as a possibility?" Lt. Mason now returns to her map to survey the situation. She measures the distance from Raybolt Depot -due north- to Crocket's Pass as 18 miles. She then phones and tries calling Lt. Col. Learned. An answering machine says the Lt. Col. is out on the maneuver but in case of emergency one should call his senior instruction pilot, Capt. Grady O' Toole. Lt. Mason immediately recalls that O'Toole also was the other person who ran with her and Lt. Lee. So Mason phones O' Toole to see if the Snowhawk might be suitable for flying and explains the emergency to him. Capt. O' Toole comments: "Yes, the Snowhawk is available for active flying status but we must checkout fuel and flight conditions down on the flight line. The flight line is about 3.5 miles away so I'll see you there in about 5 minutes."

Lt. Mason gets her maps and heads for her jeep to drive to the flight line. Mason and O'Toole meet at flight line wherein O'Toole makes following comments: "Well, it looks like the Snowhawk was cleared for flying during this afternoon's safety check. She was filled up with fuel down here on the flightline this afternoon. OK everything looks ready for a takeoff except we will need to check for weather conditions." Lt. Mason injects that she has the ham radio in the jeep and they can check for local weather conditions in the regions surrounding Crocket's Pass. The report indicates that winds are calm with no immediate snowfall in the region. All roads are clear. However, there has been an accumulation of 6" of snow in the mountains near Crockett's Pass. So, it looks like conditions are good for flying the Snowhawk. Lt. Mason and Capt. O'Toole are now sitting in the jeep looking at the map. Lt. Mason asks Capt. O'Toole if he would immediately be

ready to fly the Snowhawk to help rescue Lt. Lee. Capt. O'Toole answers:
"Affirmative."

Lt. Mason again locates the positions of the rescue operation on her map and tries to sort everything out. She has all the details and she also assumes that each stop will take an extra 5 minutes. It appears that she has a number of options to consider. So the question is: What is the quickest way to get Lt. Lee from Crocket's Pass to Fitts Field.....and how long will that take?

THIS IS THE CHALLENGE POINT:

**SEE IF YOU CAN FIGURE OUT THE QUICKEST POSSIBLE WAY TO
TRANSPORT LT. LEE FROM CROCKET'S PASS TO FITTS FIELD?**

ALL THE CLUES YOU NEED ARE GIVEN IN THE PROBLEM.

INDIVIDUAL LEARNING INSTRUCTIONS/ TEAM INSTRUCTION

E: Before we begin this study, we must receive your consent to begin. If you agree with the consent form, please sign it and we may get things underway.

HAVE SUBJECTS SIGN CONSENT FORM

Do you have any questions about the consent form?/answer questions (Confirm enrollment at local university, and ask about flight training experience) Also mention that portions of the session will be video taped and tell them you will let them know before you turn on the camera.

You are about to begin an experiment designed to study how people solve problems and learn together to complete a complex, ill-defined video-based task. In this experiment, you will first observe a video which presents and describes the JASPER problem to be solved. After the video is presented, I would like you / (both of you) to solve the problem / (together). I would like you to verbalize all your thoughts you have which go towards understanding or solving the problem. Please note you will be thinking aloud which means you are not to plan your responses. Just tell me everything you are thinking as it comes to you. Just act as if you are in the room speaking to yourself/ (each other). If you are silent for any long period of time I will ask you to talk. Please show your work on paper if need be and describe out loud what you are doing. Number your solutions steps in the order in which you proceed. The responses you make and the overall time required for solution will be recorded. Try to generate the best possible solution without making assumptions beyond those for which you can find specific evidence in the story.

If you desire, you may access any designated sequence of the video by using the MAC controller. You may do this as much as you like but note that it will use up time. I will show you how to use the controller right before you actually begin solving the problem.

But, before I start the video here is an example of someone thinking aloud about a cartoon.

PLAY THE CASSETTE AT THIS POINT

Do you understand what I want you to do?
(May mention that the cartoon is a little more philosophical than what they will be doing. What they will be doing is more realistic.)

O.K. Now I am going to start the video which will last approximately 20 minutes. The first time through I am going to ask that you just sit back and relax and listen to the tape from start to finish. You do not need to talk or solve the problem at this time. Please do not take notes or do any calculation during this first presentation of JASPER. We also ask that you not use calculators at anytime today during the entire session today.

PLAY JASPER VIDEO

This completes the Jasper video presentation. We are now ready for you/ (your team) to begin solving the problem. When you feel you have completed this problem or feel you can go no further please tell me. You will be allowed a maximum of one hour to solve the problem. I will alert you when you are within 5 minutes of the maximum time limit. Remember you may access different parts of the video as you wish, but do not play beyond the challenge point. I will be showing you this right before you start solving the problem.

AT THIS POINT DEMONSTRATE THE MAC CONTROLLER BY POINTING OUT ALL THE LOCATIONS THAT MAY BE ACCESSED BY HIGHLIGHTING THEM WITH THE LITTLE HAND. REMIND THEM THAT THERE IS NOTHING AT CUMBERLAND CITY. ALSO TELL THEM THAT THE MAP ON THE MAC IS DECEPTIVE. AND THE FLYING FIELD TECHNICALLY IS AT CUMBERLAND CITY. AND ASK THAT THEY USE THE MAP IN THE VIDEO TO MAKE THEIR CALCULATIONS FROM. SHOW THEM THE SCAN, SLOW, PLAY OPTIONS AT THE BOTTOM OF THE MAP. ASK THAT THEY TURN DOWN THE VOLUME ON THE MONITOR OR STOP THE VIDEO WHILE THEY TALKING. THEN PLAY THE CHALLENGE POINT AND STOP THE VIDEO, AND REMIND THEM THAT IF THEY NEED TO RETURN TO THIS POINT IT FOLLOWS THE LAST SCENE. CLARIFY ANY QUESTIONS, AND ALLOW THEM TO BEGIN AFTER THE RECORDER AND TIMER IS TURNED ON.

We will now take a 10 minute break. During the break we ask that not discuss the JASPER problem. Upon return you will begin problem solving on another task. When you return please meet in this room and I will show you where you will working. THE EXPERIMENTER INDICATES TO THE SUBJECT WHERE THE RESTROOM AND CANDY AND COKE MACHINES ARE.

TRANSFER PROBLEM

I would like you to please fill out this form for me. We are interested in your specific background and your viewpoint on problem solving styles. Please take about 5-10 minutes. I will let you know when we will continue. (Experimenter collects sheets when subjects finish.)

OK, we are now ready to begin your next problem solving unit. This session will require you to solve a verbal story problem. None of the problem will be presented in video format. I would like you to verbalize all the thoughts you have which go toward understanding or solving the problem. Please not that you will be thinking aloud which means you are not to plan your responses. Just tell me everything you are thinking as it comes to you. Just act as if you are alone in the room speaking to yourself. If you are silent for any long period of time I will ask you to talk. Please show your work on paper if need be and describe out loud what you are doing. Number your solution steps in the order in which you proceed. The responses you make and the overall time required for solution will be recorded. Try to generate the best possible solution WITHOUT MAKING ASSUMPTIONS BEYOND THOSE FOR WHICH YOU CAN FIND SPECIFIC EVIDENCE IN THE STORY. When you feel you have completed the problem or feel you can go no further please tell me

verbally. I will be just outside your room. Please note that for this problem you will be allowed a maximum of 40 minutes to solve it. I will alert you when you are within 5 minutes of the maximum time limit.

EXPERIMENTER DIRECTS SUBJECTS TO THEIR BOOTHS AT THIS POINT

OK, here is the written text of the REPSAJ problem you will solve. Please take 5-10 minutes to read it. The first time through we ask that you just read the script from start to finish without talking, highlighting or making any calculations. When you have finished look up at the camera, tell me you are finished and turn the script over. Then I will return to your booth and start the recorder and you will solve the problem at that time.

SUBJECT READS SCRIPT

EXPERIMENTER RETURNS AND GIVES PENCIL & PAPER TO SUBJECT. ALSO GIVES THE SUBJECT THE MAP AND REMINDS THEM THAT "ALL THE LOCATIONS THAT THEY NEED TO DO CALCULATIONS FROM ARE SHOWN ON THE MAP". YOU MAY WRITE ON THE MAP IF NECESSARY BUT, PLEASE DON'T WRITE ON THE SCRIPT. THEN READS TO THE SUBJECT THE LAST SENTENCE OF THE SCRIPT "WHAT IS THE QUICKEST WAY TO GET LT. LEE FROM CROCKET'S PASS TO FITTS FIELD... AND HOW LONG WILL THAT TAKE?"
DO YOU HAVE ANY QUESTIONS?..... STARTS RECORDER.....
REMIND SUBJECTS TO THINK OUT LOUD.

SUBJECT SOLVES PROBLEM

This part of the study is now complete. You should be scheduled to return in 3 days for a shorter session to follow-up on work today. (Confirm dates & times-emphasize importance of return session being 3 days later). Ask for comments, questions etc. We also ask that not discuss what we have done today with other people, in particular with other WSU/UD students. They may participate in the study and we don't want them to have any clues about the solutions.

E: Welcome back to your study on naturalistic problem solving and learning. In your last session you were involved in problem solving on the JASPER and REPSAJ tasks. During your exposure to these problems you encountered a number of different situations, attributes, and values necessary to complete a solution. Today, I would like to test your memory for some of these items. This booklet contains all the questions relating to the problems. If you do not know the answer to a question, skip it and go on to the next one. You will be evaluated on the overall percent of questions you answer correctly. You will be allowed 30 minutes to complete this test. When you are within 5 minutes of the allowable time, I will let you know. You do not need to talk while you are answering the questions. When you are done answering the questions, please let me know. I will give you a debriefing after you have finished the test. I will not be available for question clarification during your recall time.

GIVE THE TEST AT THIS POINT

AFTER EVERYONE HAS COMPLETED THE TEST READ YOUR DEBRIEFING

THEN THE FOLLOWING CONCLUSION

Before you leave today I would like to once again remind you to please not discuss what we have done in this experiment with other people. In particular with other college (WSU) students, we would like for them to have as much fun as you have had solving these problems. Also we will be giving subjects the opportunity to see the solution to both JASPER & REPSAJ problems. This will be after we have finished the experiment possibly sometime in December or January. If you would like to sign up to be notified let me know now. This solution session will probably take about a 1/2 hour, and we may not be able to pay you for that time. Do you have any further questions or comments?

TITLE: Cooperative Analogical Problem Solving (CAPS)

I, _____ am participating because I want to.
The decision to participate in this research study is completely voluntary on my part. No one has coerced or intimidated me into participating in this program.

_____ has adequately answered any and all questions I have asked about this study, my participation, and the procedures involved, which are set forth in the addendum to this Agreement, which I have initiated. I understand that the Principal Investigator or his designee will be available to answer any questions concerning procedures throughout this study. I understand that if significant new findings develop during the course of this research which may relate to my decision to continue participation, I will be informed. I further understand that I may withdraw this consent at any time and discontinue further participation in this study without prejudice to my entitlements. I also understand that the Medical Consultant for this study may terminate my participation in this study if he/she feels this to be in my best interest. I may be required to undergo certain further examinations, if in the opinion of the Medical Consultant, such examinations are necessary for my health or well being.

I understand that my entitlement to medical care or compensation in the event of injury are governed by federal laws and regulations, and that if I desire further information I may contact the Principal Investigator.

I understand that for my participation in this project I shall be entitled to payment as specified in the DoD Pay and Entitlements Manual or in current contracts.

or

I understand that I will not be paid for my participation in this experiment.

I understand that my participation in this study may be photographed, filmed or audio/videotaped. I consent to the use of these media for training purposes and understand that any release of records of my participation in this study may only be disclosed according to federal law, including the Federal Privacy Act, 5 U.S.C. 552a, and its implementing regulations. This means personal information will not be released to an unauthorized source without my permission.

I FULLY UNDERSTAND THAT I AM MAKING A DECISION WHETHER OR NOT TO PARTICIPATE. MY SIGNATURE INDICATES THAT I HAVE DECIDED TO PARTICIPATE, HAVING READ THE INFORMATION PROVIDED ABOVE.

Volunteer Signature _____ SSAN _____ DATE _____

Witness Signature _____ SSAN _____ DATE _____

Principal Investigator _____ SSAN _____ DATE _____

CONSENT FORM

TITLE: Cooperative Analogical Problem Solving (CAPS)

You are invited to participate in an experiment designed to study how people problem solve and learn together to complete a complex, ill defined video-based task. The experiment you participate in will be useful for understanding how teams and individuals interact to acquire and access knowledge in complex situations. This understanding will help facilitate the system design of cooperative man-machine systems. Your exposure to the equipment is limited to your watching the CRT screen at a distance of about 2 feet for approximately two hours for Session 1, and one hour for Session 2, occurring three days after Session 1. This does not involve any known risks. You will be given the opportunity to take a rest about half way through Session 1.

In this experiment, you will be observing a video-generated display consisting of an ill-defined naturalistic problem. Your response will consist of "thinking aloud" to solve the problem. Any paper/pencil work which is necessary will be documented. After completion of the first video-based problem, a second problem will be given to you in a text-based format. Again, your response will be to "think aloud". You will receive further detailed instructions at the beginning of the experiment.

The responses you make, and the times at which you make them will be recorded for later analysis. Audio and video recordings will also be made for subsequent study. Your name will be recorded along with the dates and times which the experiment is performed. Your confidentiality as a participant in this project will be protected. Your identity will only be revealed in accordance with the Privacy Act, 5 USC 552 and its implementing regulations. A numeric code will be used to identify the data in any publication.

Any monetary benefits will be in accordance with LTSI/Air Force agreements.

You are free to refuse to participate or to withdraw your participation in the experiment at any time. Doing so will not prejudice your relation with the Laboratory in any respect.

Any questions you may have should be directed to Mr Michael McNeese (58805).

Your willingness to participate in this experiment is greatly appreciated. Your signature indicates that you have decided to participate, having read the information provided above.

YOU WILL BE GIVEN A COPY OF THIS FORM TO KEEP.

SIGNATURE _____ DATE: _____

Recall/Recognition Test Materials

Instructions: Please answer the following questions to the best of your ability based on your memory of the Jasper II and REPSAJ problems which you participated in 3 days ago. You may have up to an hour to do this task. Your responses to the multiple choice/fill-in-the-blank questions will be scored: on the basis of the number of questions answered correctly/total number of questions asked. Each of these questions is worth 2.5 points each. Please encircle the correct letter which is indicative of the right answer for multiple choice items. Please take your time, you are not being evaluated on how fast you answer but rather on the accuracy of your answers. If you get stuck go on to the next question. If you have any questions ask them now.

Part 1: Repsaj Problem

1. _____ was the name of the flying vehicle in this problem.
2. How much fuel did the flying vehicle hold when completely filled up?
a.) 10 gals b.) 12 gal c.) 3 gal d.) 5 gal
3. What did Lt Col Learnad do in the problem?
a.) drove a jeep b.) conducted an overview briefing c.) performed the rescue
d.) cut the grass
4. _____ was the speed limit on Route 814 which connected Fitts Field and _____ Raybolt Depot.
5. Lt Debra Mason weighed how many pounds?
a.) 120 b.) 180 c.) 135 d.) 110
6. The name of the Doctor in REPSAJ is _____.
7. Lt Valery Lee suffered the following type of injury at Crockett's Pass:
a.) broken arm b.) sprained ankle c.) frostbite d.) lacerated head
8. The flying vehicle carries in its cargo area:
a.) a stretcher b.) a backpack c.) a generator d.) a toolbox
9. The communications Sargent who generated the emergency broadcast from _____ Raybolt Depot was named _____.
10. There was an accumulation of how much snow in the mountains near Crockett's Pass?

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PUTTING KNOWLEDGE TO USE: THE ACQUISITION AND TRANSFER
OF KNOWLEDGE IN SITUATED PROBLEM SOLVING ENVIRONMENTS
(U) ARMSTRONG LAB WRIGHT-PATTERSON AFB OH CREW SYSTEMS

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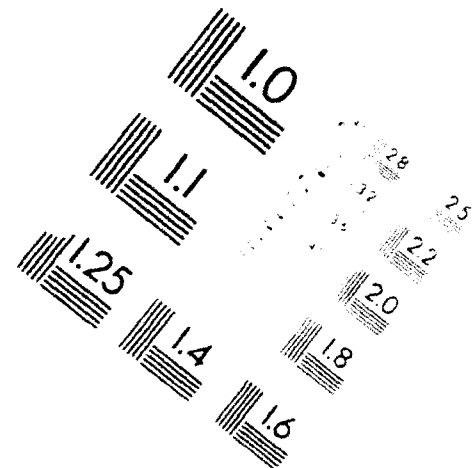
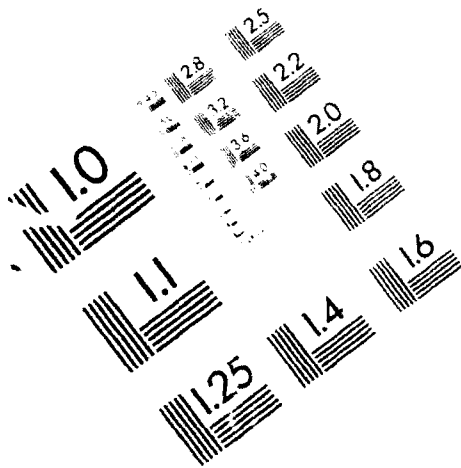


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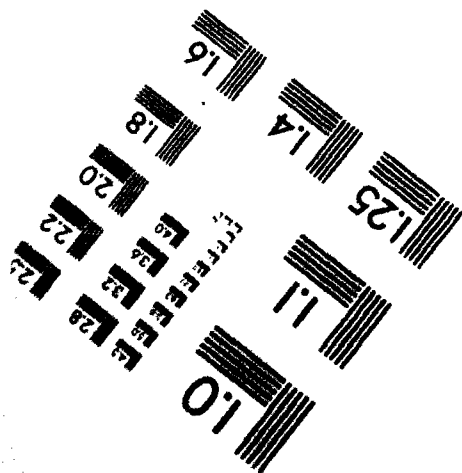
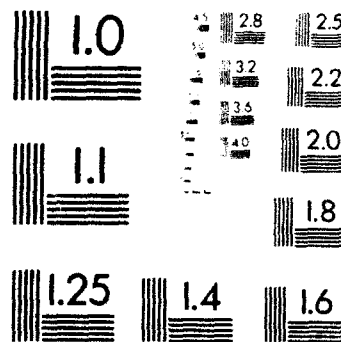
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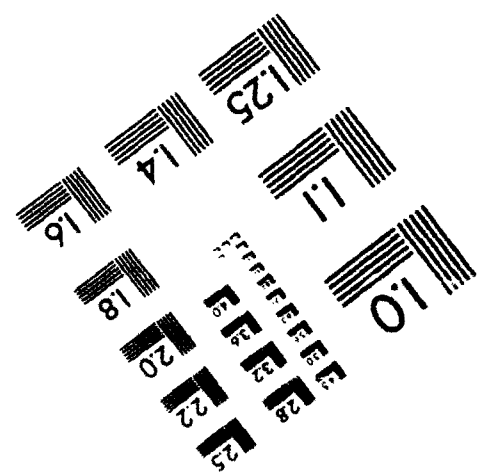
Centimeter



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a.) 3 inches b.) 1 foot c.) 2 feet d.) 6 inches

11. The problem assumes that each stop of the flying vehicle will take
-----.

12. Who did Lt Mason sit in a jeep with?

a.) Lt Lee b.) Col Learnad c.) Capt Turpin d.) Capt O'Toole

13. Lt Mason was scheduled to be on duty the night of the rescue at the :

a.) communications center b.) computer center c.) Fitts infirmary
d.) flighline

14. The flying vehicle got how many miles per gallon on a fillup?

a.) 5 mpg b.) 35 mpg c.) 18 mpg d.) 9 mpg

15. What is the minimum distance required to land the flying vehicle?

a.) 1500 yds b. 200 ft c. 120 yds d. 80 yds

16. How far was Crocket's Pass from Raybolt Depot? _____

17. How much extra fuel could be carried in the cargo area of the flying vehicle?

a.) 3 gal b.) 5 gal c.) 6 gal d.) 1 gal

18. Lt Lee weighs:

a.) 130 lbs b.) 110 lbs c.) 100 lbs d.) 119lbs

19. What is the weight of 1 gal of premium fuel used in the flying vehicle?

a.) 3 lbs b.) 10 lbs c.) 8lbs d.) 6 lbs

20. The flying vehicle could cover _____ mile(s) every 1.5 minutes of flight.

Part 2: Jasper problem

1. The name of the service station attendant in the video was _____.
2. The ultralight maximum payload is:
a.) 220 lbs b.) 500 lbs c.) 95 lbs d.) 120 lbs.
3. What could be attached behind the seat in the ultralight?
a.) a light b.) a rope c.) a box d.) a radio
4. How far was Boones Meadow from Hildas?
a.) 60 miles b.) 15 miles c.) 65 miles d.) 30 miles
5. The total weight of the fuel in the ultralight tank is :
a.) 30 lbs b.) 57 lbs c.) 40lbs d.) 15lbs
6. How many miles per gallon did the ultralight perform at:
a.) 27 mpg b.) 15 mpg c.) 30mpg d.) 33 mpg
7. Cumberland was _____miles away from Hildas?
8. Boones Meadow had a landing strip available which was how long?
a.) 1000 ft b.) 1500 ft c.) 2000 ft d.) 2500 ft
9. The eagle was injured by:
a.) another animal b.) a gun shot c.) a car d.) a forest fire
10. How long would it take for a car to go from Cumberland to Hildas?
a.) 20 minutes b.) 2 hours c.) 1 hour d.) 30 minutes
11. Dr Ramirez emphasized to Emily that:
a.) time is of the essence to save the eagle
b.) eagles live to be 10 years old
c.) eagles get car sick
d.) he should tell Larry how to help the eagle by giving instructions over the ham radio.
12. While in the restaurant, what does Emily order for dessert:
a.) lemon jello b.) apple pie c.) cheese cake d.) strawberry ice cream
13. Larry weighed in at _____lbs at the restaurant scale.

14. What did Larry carry the eagle in after it was injured?
a.) a garbage bag b.) a burlap sack c.) a newspaper d.) a T shirt
15. The ultralight's cruising speed on a calm day was _____ miles per hour
16. The Doctor suggested that a good estimate for the weight of an eagle is _____?
17. Why was access into Boones Meadow so hard?
a.) it was surrounded by a lake
b.) there was ice on the roads
c.) there were no roads into the area
d.) a bridge was washed out
18. How many miles was it on foot from Hildas to Boones Meadow?
a.) 9 miles b.) 22 miles c.) 4 miles d.) 18 miles
19. How long did it take to walk from Hildas to Boones Meadow _____?
20. The ultralight has a fuel tank with a maximum capacity of _____ gals

-----please be sure to turn your test paper into the experimenter-----

DEBRIEFING

You have just participated in a study to compare the effects of a cooperative learning or individual learning setting upon subsequent analogical problem solving. You participated in the (cooperative or individual) setting. We have purposely selected an ill-defined, complex source problem, entitled *Jasper2: Rescue at Boones Meadow*, which was presented within a perceptual, naturalistic context. After the source problem, you were presented with the *REPSAJ* transfer problem, which is a close analogy of the *JASPER 2* problem. In all cases, everyone worked on the *REPSAJ* problem individually. Both problems used in this study required you to set up the problem prior to solving it.

We wish to examine these various conditions to arrive at what counts for success in cooperative learning groups and to know whether these groups do better than individuals in terms of knowledge transfer to similar problems, encountered in future endeavors. It is our hypothesis that cooperative learning does lead to better transfer than individual learning settings. However, it is expected that the specific types of individual or group activity experienced will be a better indicator of positive transfer. We will analyze your transcripts to determine the prevalence of particular types of these learning or meta-cognitive activities. The relative effectiveness of these activities to enable transfer of knowledge will then be obtained. The data which you have provided us will be invaluable in verifying these hypotheses. This research has implications in many areas of human performance, learning, memory, and cognition with particular application in the way we solve everyday problems.

Unless you have any further questions or comments, you are free to go.

Thank you for your time and effort and your willingness to participate.

APPENDIX B
DATA ANALYSIS PLAN

An Overview of the Data Analysis Plan

The goal of this overview is to take a brief look at my Ph.D. thesis in terms of: 1) the scoring/measures of performance and 2) the experimental analysis of data. Within the first topic, the main concern is to look at the logical clusters of dependent measures used to assess performance. The second topic focuses on the overall structure and philosophy of the experimental analysis, provides a brief view of each experimental design perspective, and elaborates the sequence of tests used for the experimental analysis. Together these two topics form the foundation to evaluate the hypotheses elaborated in my thesis proposal.

General Scoring/Measures

Because I have obtained a large number of dependent measures, a decision was made to classify related measures to a given cluster which could then be analyzed from a global-to-local viewpoints. A large number of measures were collected to show the practical implications of cooperative learning and the transfer of knowledge from multiple perspectives. In order to maintain a foundation for future research practice, measures related directly to problem content and problem performance were assessed. Overall, I collected up to a total of 33 different scores/measures which could be used in the analysis. These measures were assigned to one of four clusters. Clusters 1 and 2 are directly indicative of problem content and subjects' experience in solving the Jasper/Repsaj problems. Both of these clusters consist of measures which are obtained directly from scoring two different types of protocol analyses currently used by the Cognition and Technology Group at Vanderbilt (see Goldman, Vye, Williams, Rewey, & Pellegrino, 1991). Clusters 3 focuses on performance measures while Cluster 4 focuses on

memory/recall measures.

Cluster 1, based on the *problem space* protocol analysis procedure, consists of the following measures: range mentioned, time mentioned, payload mentioned range attempted, time attempted, payload attempted, range solved, time solved, and payload solved, landing, multiple vehicles, multiple pilots, multiple routes, and compare times. Each of these measures were scored according to the % of subjects, in a given condition which obtained the problem element under question in their problem space. For example, 30% of the individuals solving Jasper may have obtained the range solved element while 60% of the groups obtained the range solved. Hence, the protocols were scored to reveal these percentages for each problem element in the problem space. Additionally, Cluster 1 included the measure, % problem elements solved, which represents how well subjects did in terms of their percent of problem elements they obtained out of the total number possible. This is more of a summative measure and for example if a subject scored 70%, it would indicate that that person had obtained 70% of all the possible problem space elements as revealed by their protocol.

Cluster 2, based on the *statement type* protocol analysis procedure, was scored according to a structured protocol which rated each statement in a subject's protocol according to whether it contained very specific instances of the categories types: goal, state, means, outcome, metacognitive monitoring, misconceptions, and 'other'. Therein, after collapsing across specific instances to sum a total for each category, the number of statements in any given category are divided by the total number of statements in a subject's protocol to compute the percentages for each statement type generated by a subject(s). The measures then consisted of % goals generated, % states generated, % means generated, % outcomes generated, % metacognitive monitoring generated, % misconceptions generated, and % 'other' generated.

Cluster 3, is focused on performance measures and relatively straightforward.

These measures consists of time on task (either Jasper or Repsaj dependent on analysis), talk aloud efficiency (i.e., total number of words generated/ time on task), and number of initiatives recorded to access the Jasper laserdisc.

Cluster 4, is focused on memory/recall measures and is only utilized for evaluating the Repsaj transfer problem and the memory task. Cluster 4 variables are not used for the Jasper Analyses. The measures consist of total recall, Jasper recall, Repsaj recall, recall task time, and % problem elements transferred. The first four measures are obtained from the memory task which occurs after the Repsaj problem is performed. The last variable, % problem elements transferred, is a very salient one which directly evaluates the total amount of transfer from Jasper-to-Repsaj. It evaluates 'how much' transfer occurs from acquisition to transfer given a group-to-individual research paradigm. Note that this variable does not evaluate 'the what' of transfer but rather addresses the total amount of transfer.

Experimental Analysis of Data

Because of the practical difficulties in recruiting/running teams for experimentation, the long lead times required to perform protocol analysis across all the transcripts, the large number of dependent variables assessed, and the necessity of employing a complex group-to-individual transfer paradigm; the overall data analysis philosophy emphasizes a wholistic/naturalistic approach; whereby, one extracts the greatest detail from the data. The analyses performed clarify what counts for success in cooperative learning and particularly highlight the conditions contributing to knowledge transfer from the acquisition-to-the-transfer problem. Results are provided for four primary Experimental Design Perspectives: A-T 1, A-T 2, A-T 3, A-T 4; for each of the respective clusters previously described. Each perspective addresses different aspects of the hypotheses identified in the proposal and

represents specific relationships between independent and dependent variable clusters. Each perspective contains distinct analysis platforms for acquisition (A) and transfer (T) performance; thereby resulting in a total of eight analyses. A given experimental design contained under an *acquisition* analysis platform (eg, A-1) is indexed (ie., shares the same perspective) with a corresponding experimental design contained in the *transfer* analysis platform (eg, T-1).

Briefly, the following description reviews each perspective to be considered: **experimental design perspective A-T 1** assesses relationships between Learning Setting (group, individual, or pseudo-group) and Collective Induction (shared or dominant groups), wherein dominance in a group is determined by amount of talking present/observation, **experimental design perspective A-T 2** assesses Learning Setting and Collective Induction, wherein dominance in a group is determined on the basis of cognitive assessment provided by the protocol analysis, **experimental design perspective A-T 3** assesses the relationships between Quality of Solution (above average, below average) and Learning Setting, and **experimental design perspective A-T 4** assesses the relationship between MetaCognitive Strategies (meta-monitoring or solution elaboration) and Learning Setting. Results are consequently reported beginning with the acquisition platform and ending with the transfer platform in sequence for experimental design perspectives 1 to 4.

For each analysis in a perspective, the evaluation is based on a hierarchical plan which evaluates data first at the tree level, then progresses to a branch level, and finally takes a very specific view at the leaf level. This is in accordance with the methods utilized by Kamouri, Kamouri, & Smith (1986) for their studies involving multiple dependent variables to assess analogical transfer, and by Lambiotte, Dansereau, O'Donnell, Young, Skaggs, & Hall (1988) in their hierarchical approach to the evaluation of cooperative learning and transfer. The hierarchical progression first utilizes a Multivariate Analysis of

Variance (MANOVA), to evaluate all the measures assigned to a given cluster if applicable. This results in MANOVAs being applied to Clusters 2, 3, and 4 to evaluate the global main effects and interaction effects of the cluster under question. For example, in T-4, there would be separate 2 x 3 Between Groups MANOVAs applied to Clusters 2, 3, and 4 to evaluate the main effect of learning setting and MetaCognitive Strategy by testing for significance in each appropo cluster. Cluster 1 measures are only appropriate for Chi-Square Analyses and as a consequence are not evaluated at the tree level by a MANOVA. However, the application of an ANOVA on the % problem elements solved (a summative measure of the problem space) is used to evaluate the significant main main effect of the variables under question within a given experimental design perspective.

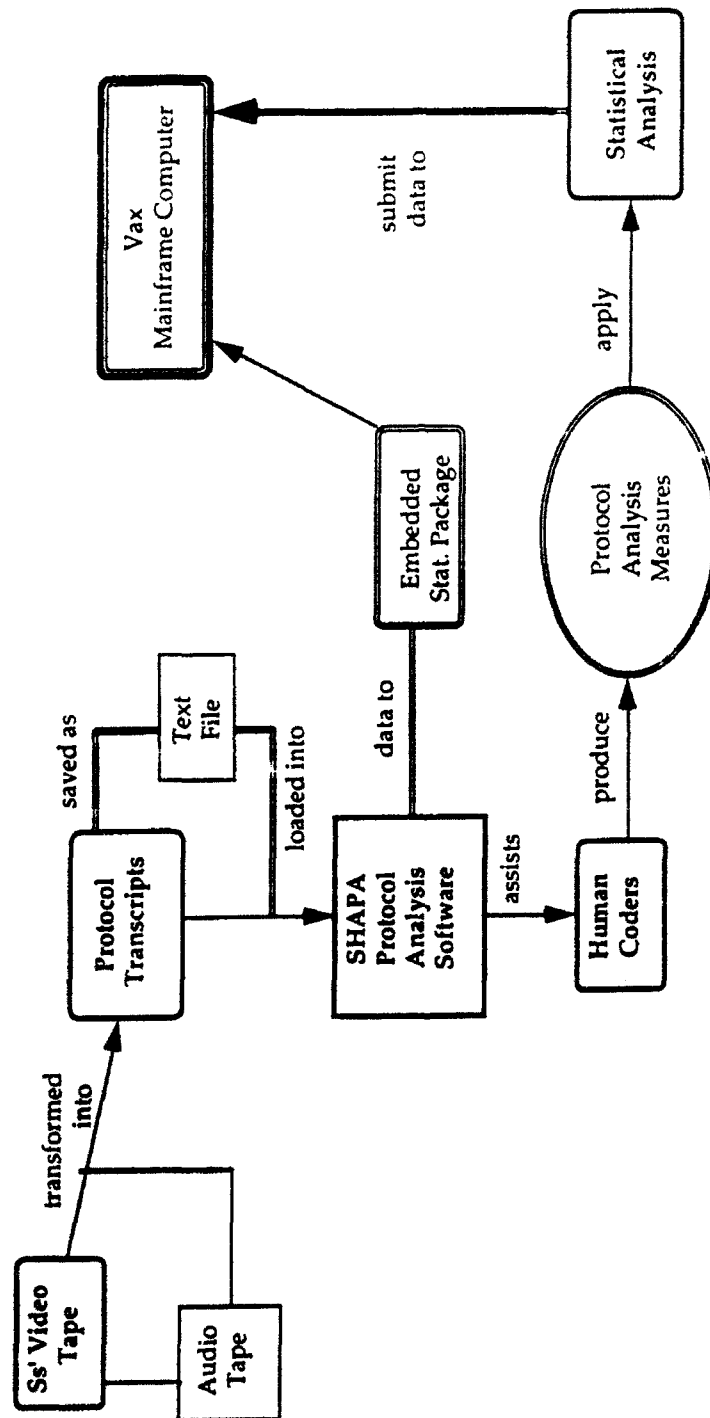
After the MANOVAs are conducted for each cluster, the use of an ANOVA on each specific measure within a cluster is performed to discern branch level effects of the independent variables on specific dependent measures. At the leaf node, LSD comparisons and/or t-test pairwise comparisons are performed on these specific dependent measures to show discrete differences in the effects of different levels of a variable(s). For example, for analysis A-1, I can contrast the performance of shared groups with dominant groups on the dependent measure, talk aloud efficiency.

Hence, the hierarchical approach to the sequence of analysis allows one to observe findings at a global level but affords a more fine-grain view at local level of phenomenon. Figures used in the dissertation writeup focus on showing the specific leaf level findings to portray many of the intricacies underlying the basic question, "What counts for success in cooperative learning?" and to further understand the original research question put forth in the proposal, "What are the conditions in group collaboration that a lead to a group member's use of knowledge as an individual?" Although the tree-level view affords more of a theoretical approach to the data, the leaf-level view places emphasis on the post hoc nature of analysis to yield comparisons for practical utility. Also, the leaf-level designates

new terrain for extensions of the original predictions in areas which have not been tested prior to this experimentation (eg, the adaptive benefits of solution elaboration and meta-monitoring, two distinct types of metacognitive strategies) as they differentially effect acquisition and transfer performance. In a sense, the assessment of the pairwise comparisons provide a kind of 'proving grounds' for the establishment of innovation in the next generation of research in cooperative learning. To only look at the higher-order effects would likely mask some of the more interesting and useful findings. On the other hand, the higher-order effects are useful to begin establishment of a viable theoretical position in understanding cooperative learning and the transfer of knowledge for future endeavors.

Data Analysis: Process

Do for Jasper & REPSAJ



APPENDIX C
ILLUSTRATIONS OF DATA

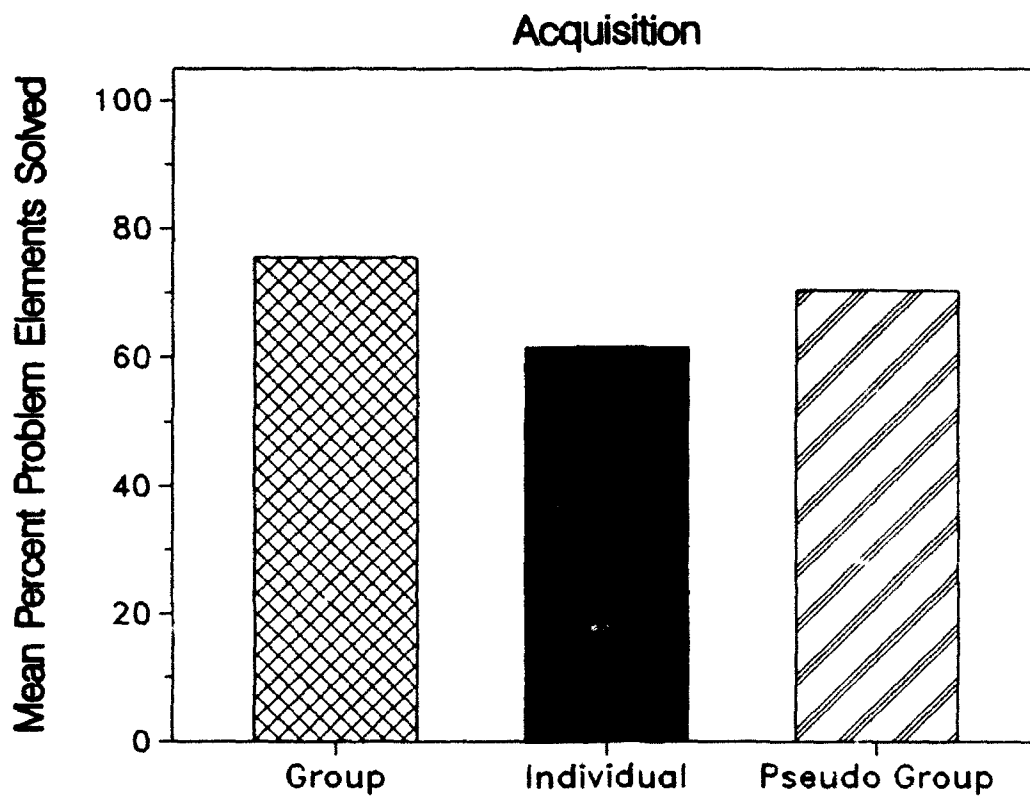


Fig. 5. Primary summary variable for Jasper Learning Setting conditions.

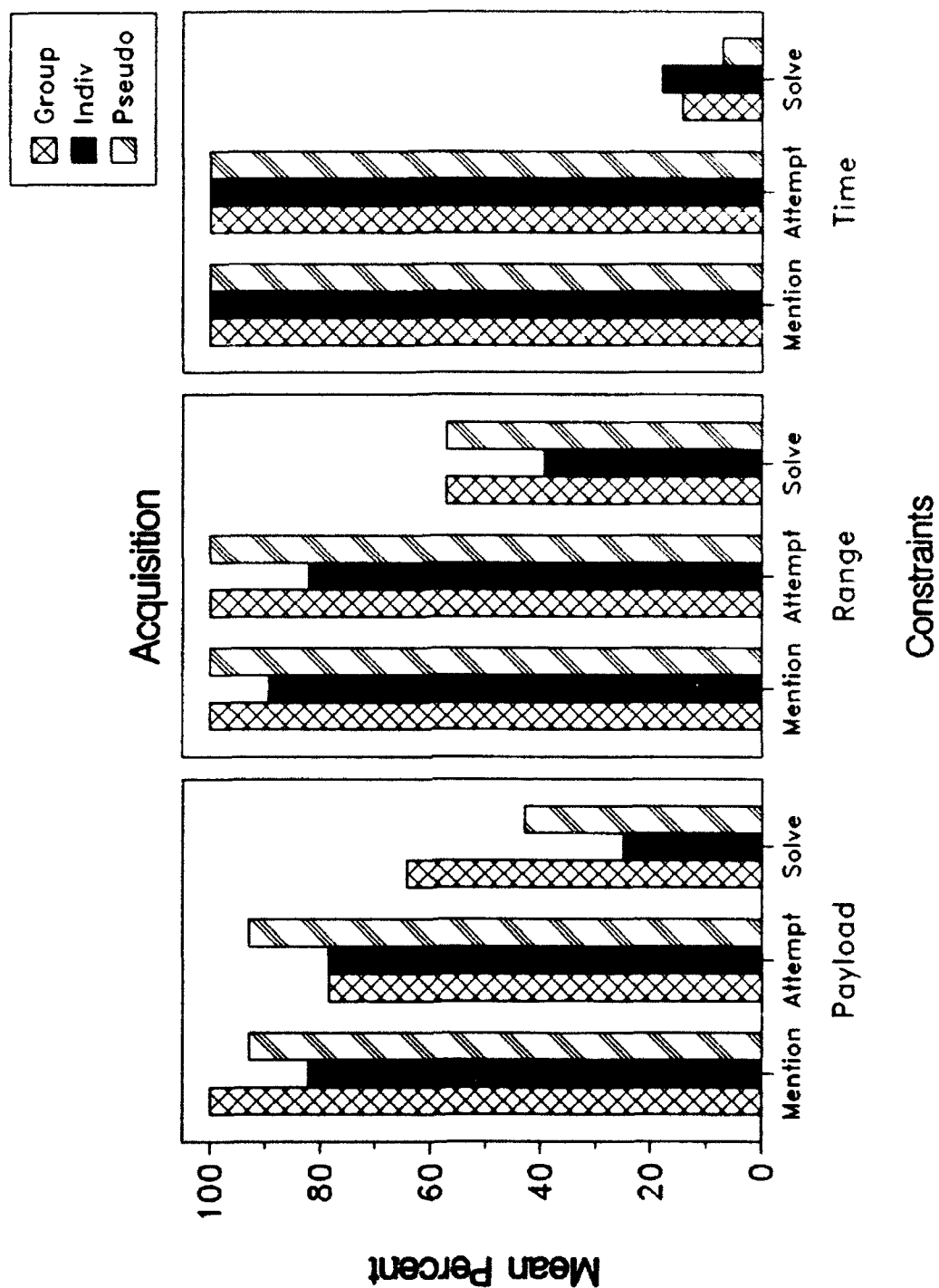


Fig. 6. Percentage of subjects including Jasper solution space elements for Learning Setting conditions.

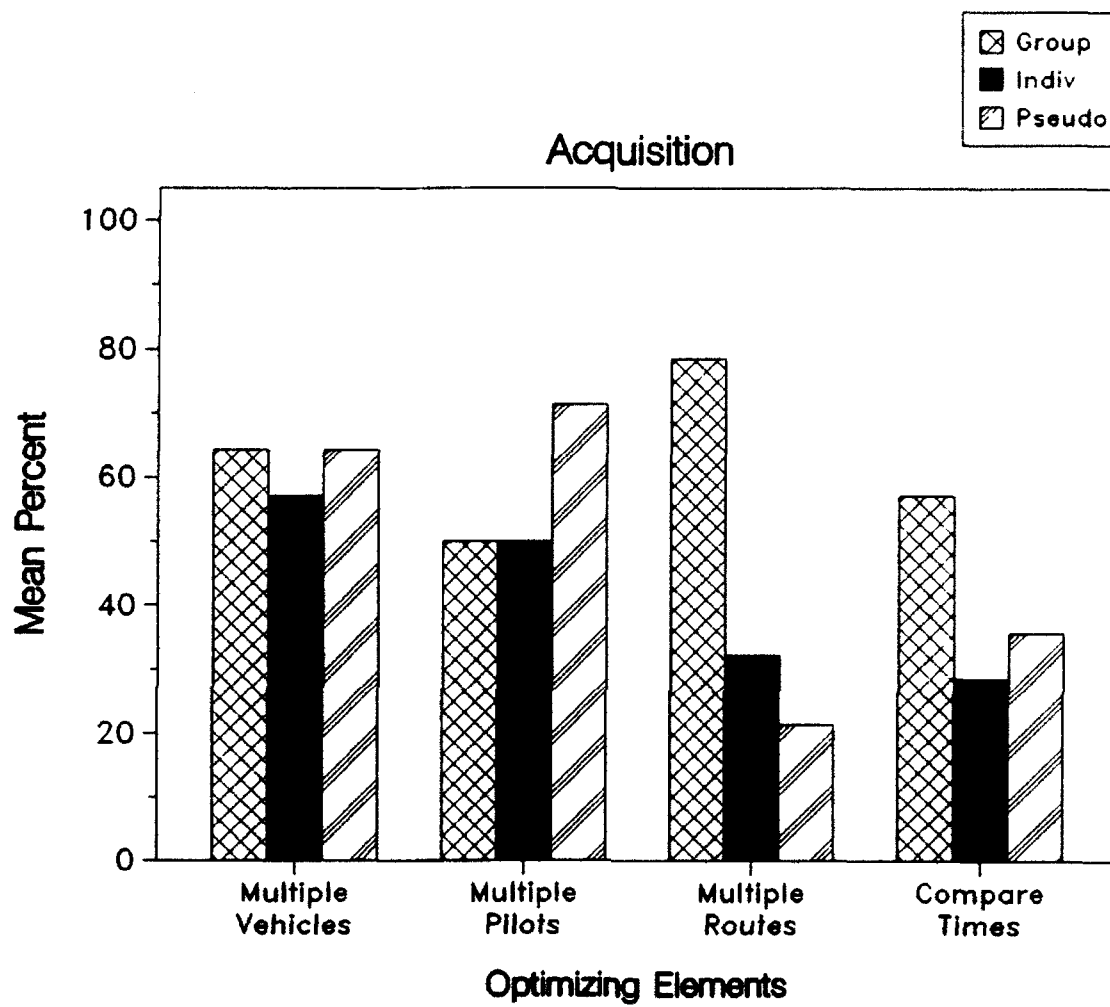


Fig. 7. Inclusion of Jasper optimizing elements for Learning Setting conditions.

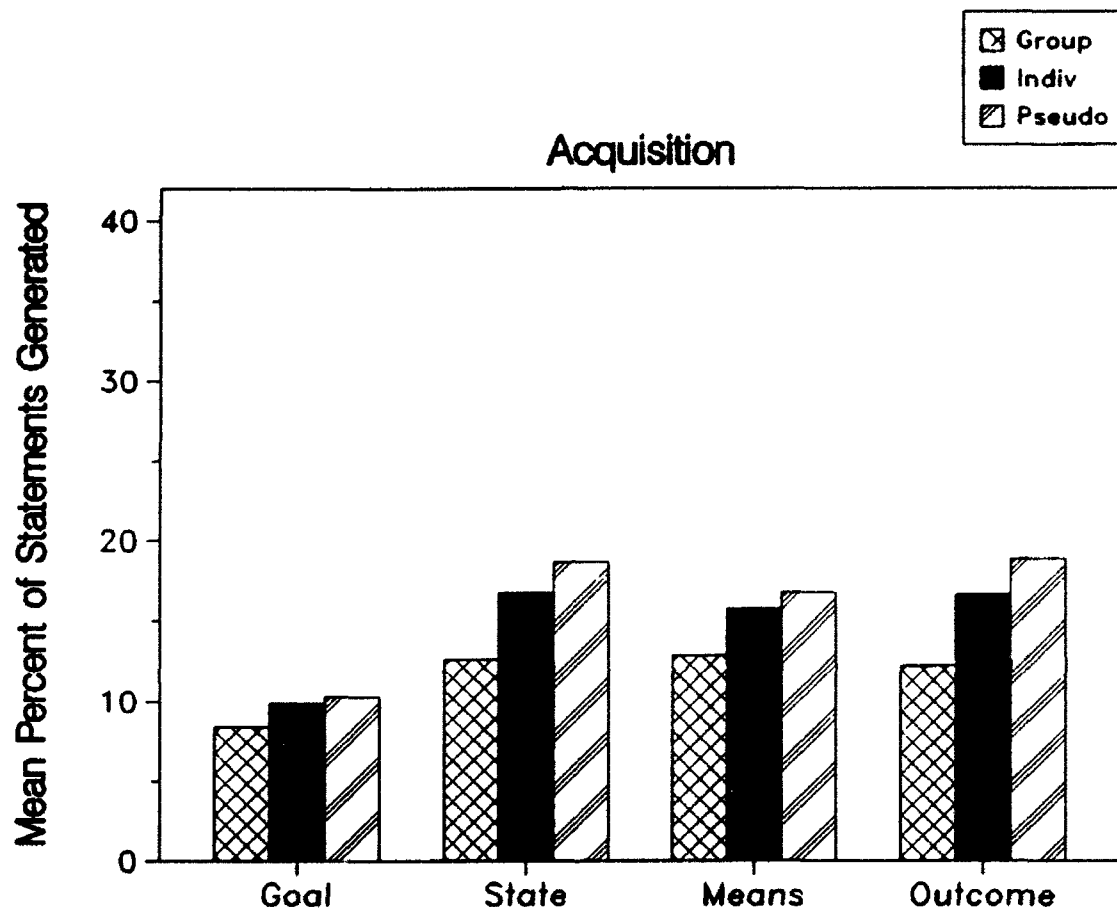


Fig. 8. Learning Setting analysis of goal, state, mean, and outcome statements for Jasper.

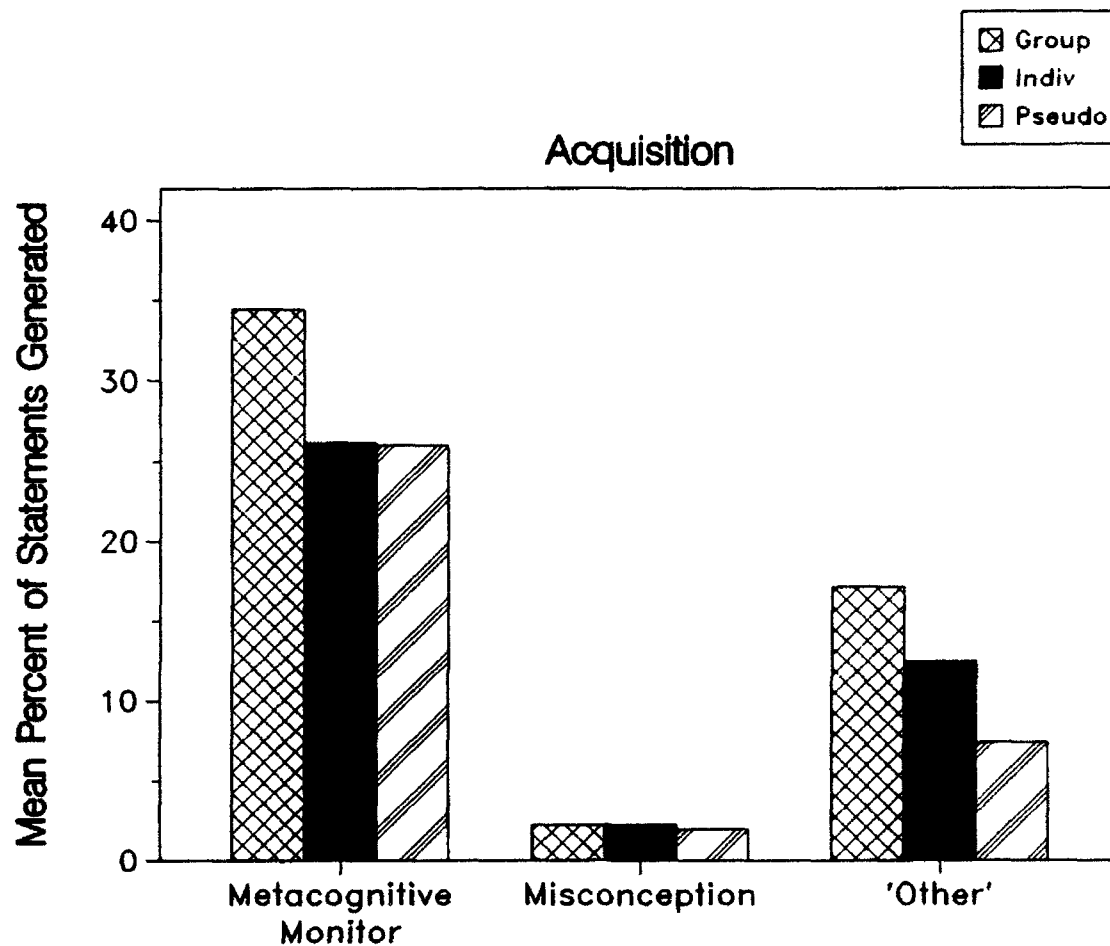


Fig. 9. Learning Setting analysis of metacognitive monitoring, misconception, and other statements for Jasper .

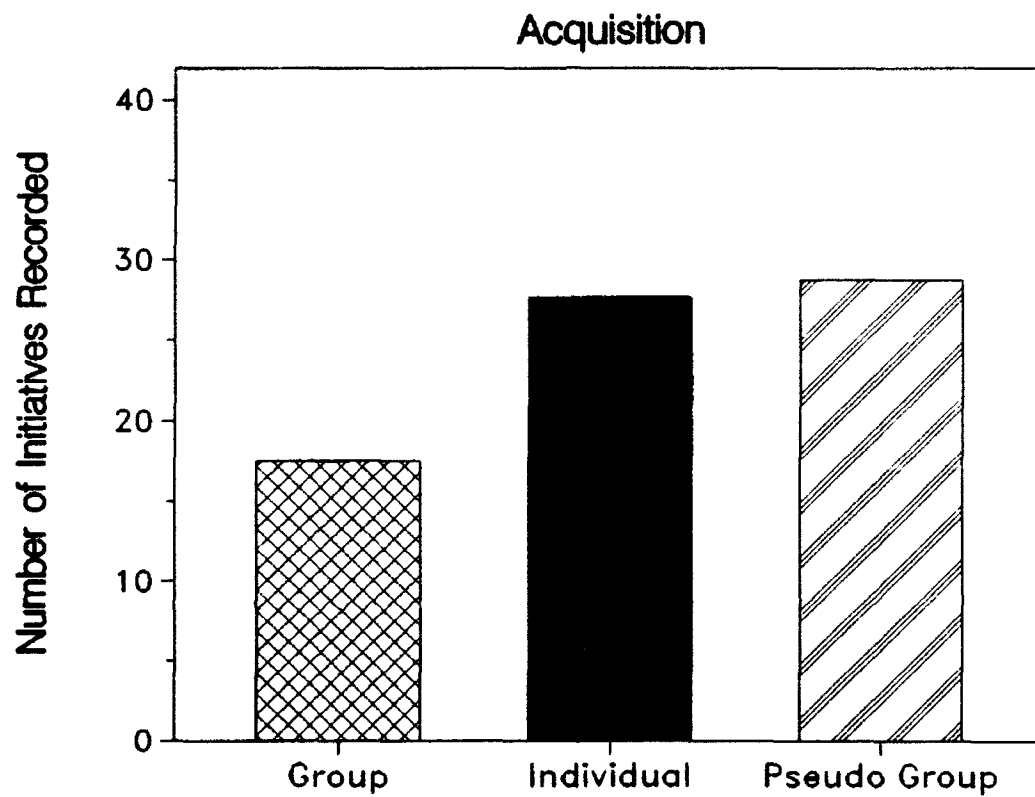


Fig. 10. Number of initiatives recorded to activate the Jasper videodisc.

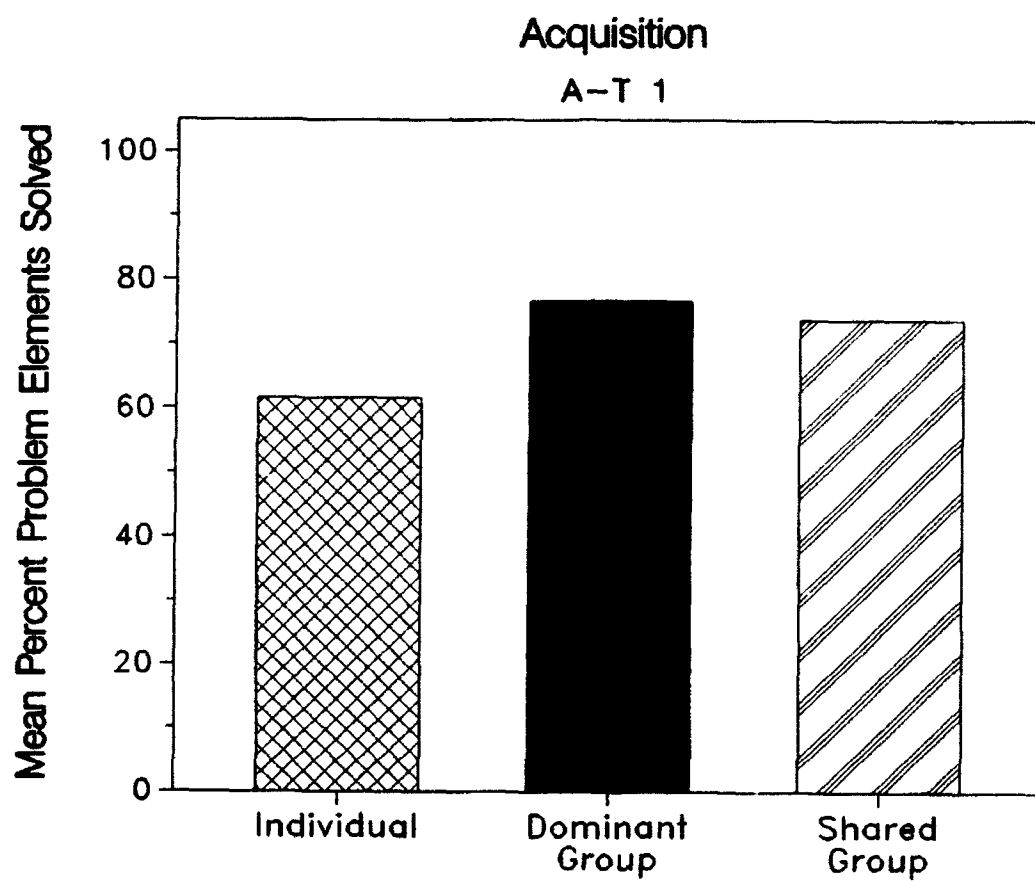


Fig. 11. Primary summary variable for Jasper Collective Induction conditions.

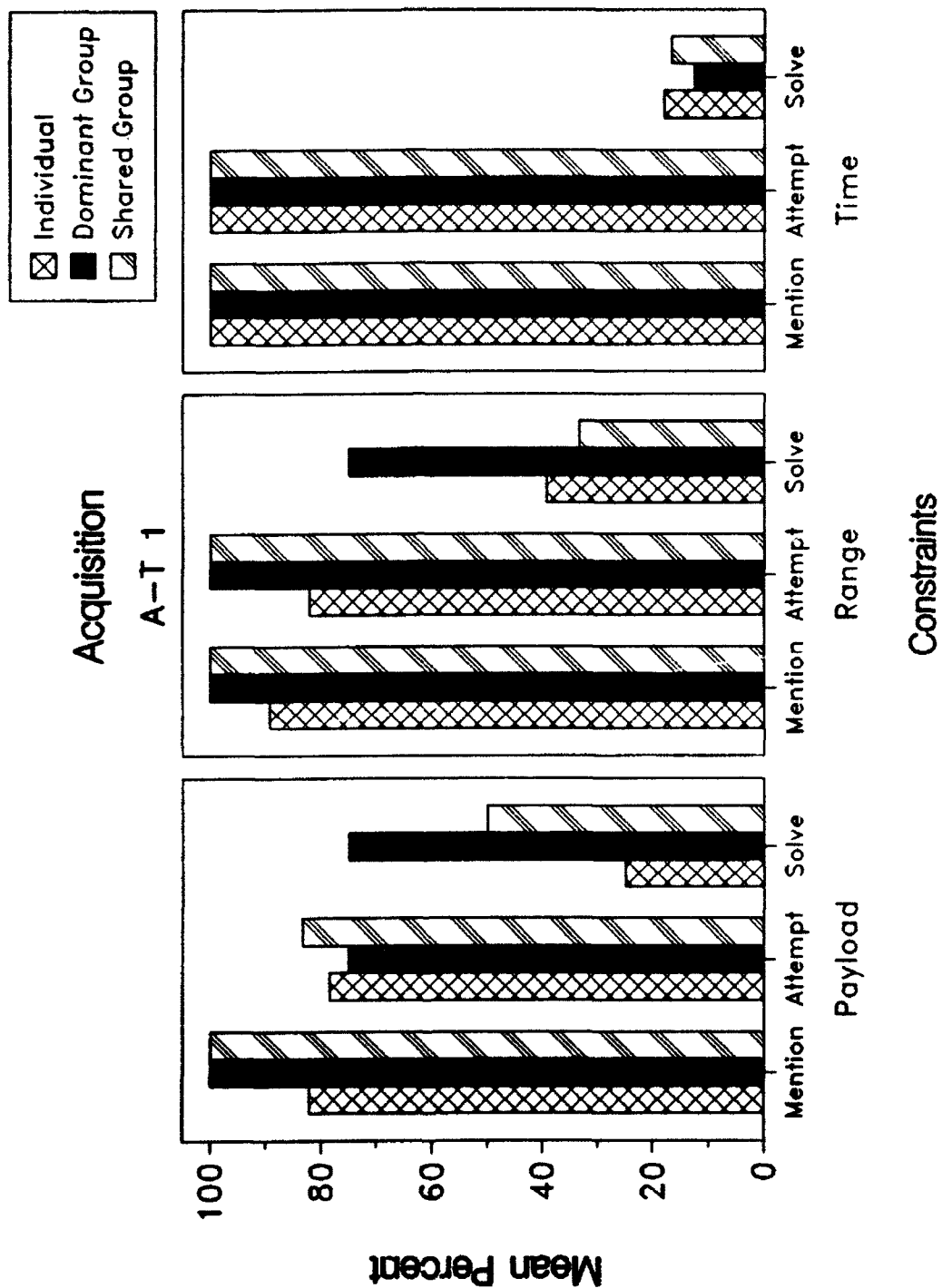


Fig. 12. Percentage of subjects including Jasper solution space elements for Collective Induction conditions.

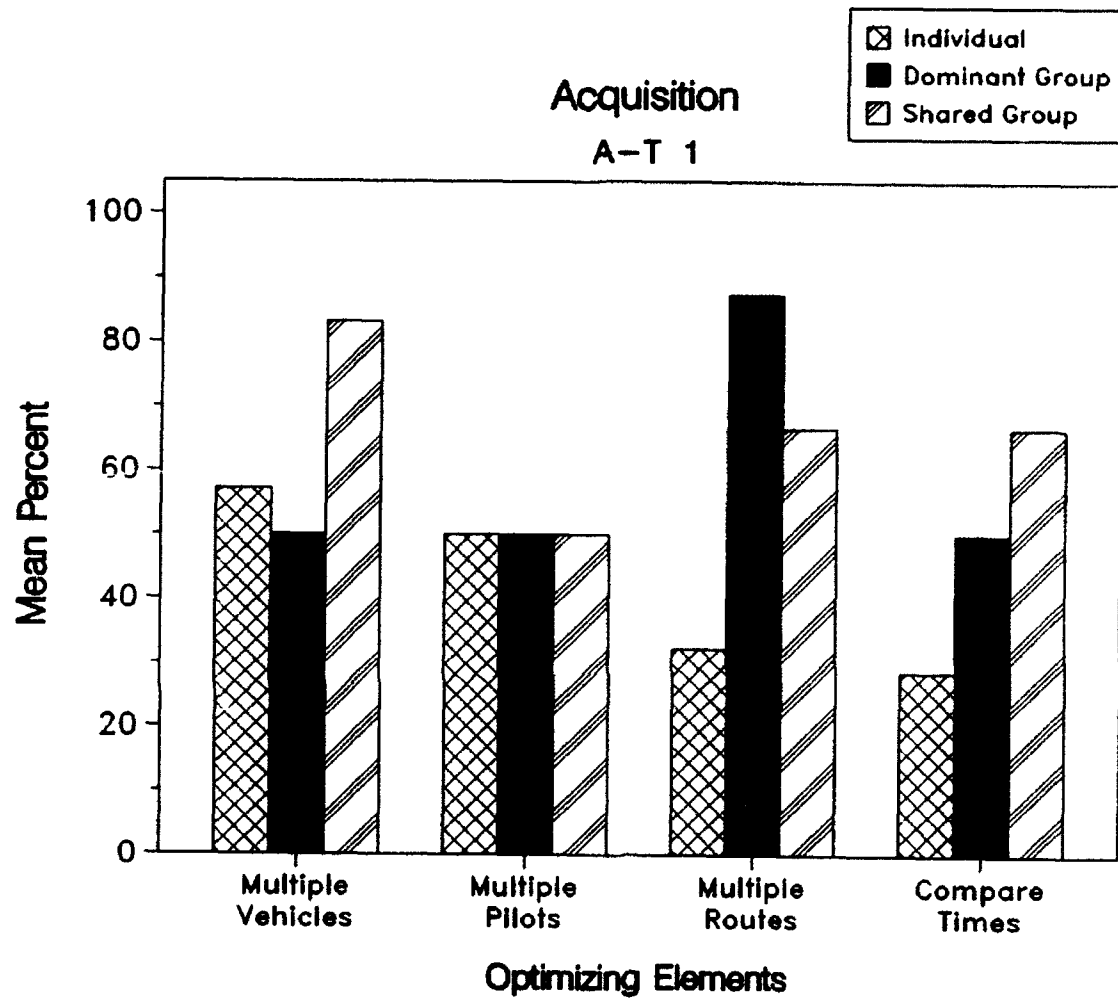
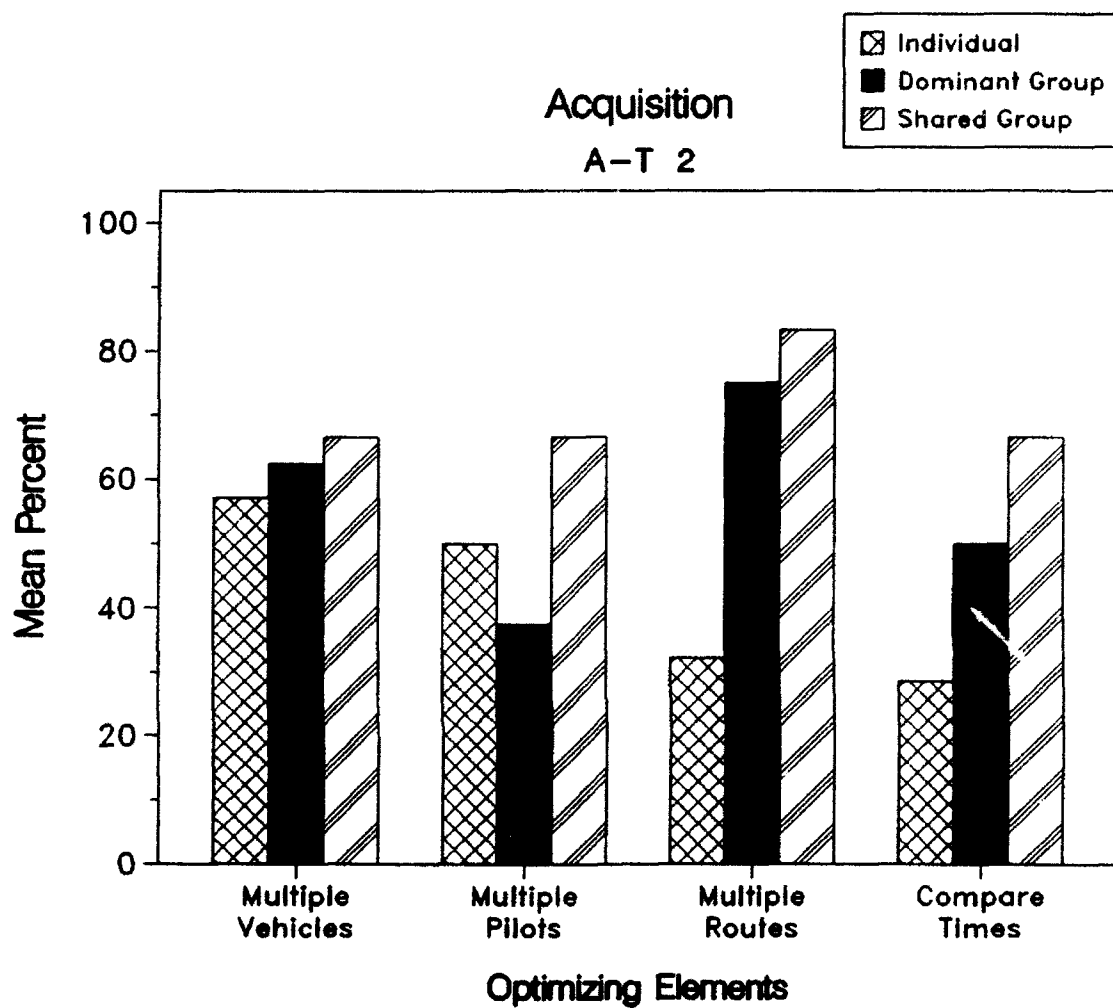


Fig. 13. Inclusion of Jasper optimizing elements for Collective Induction conditions.



**Fig. 14. Inclusion of Jasper optimizing elements for Collective Induction conditions.
(based on cognitive contributions criterion)**

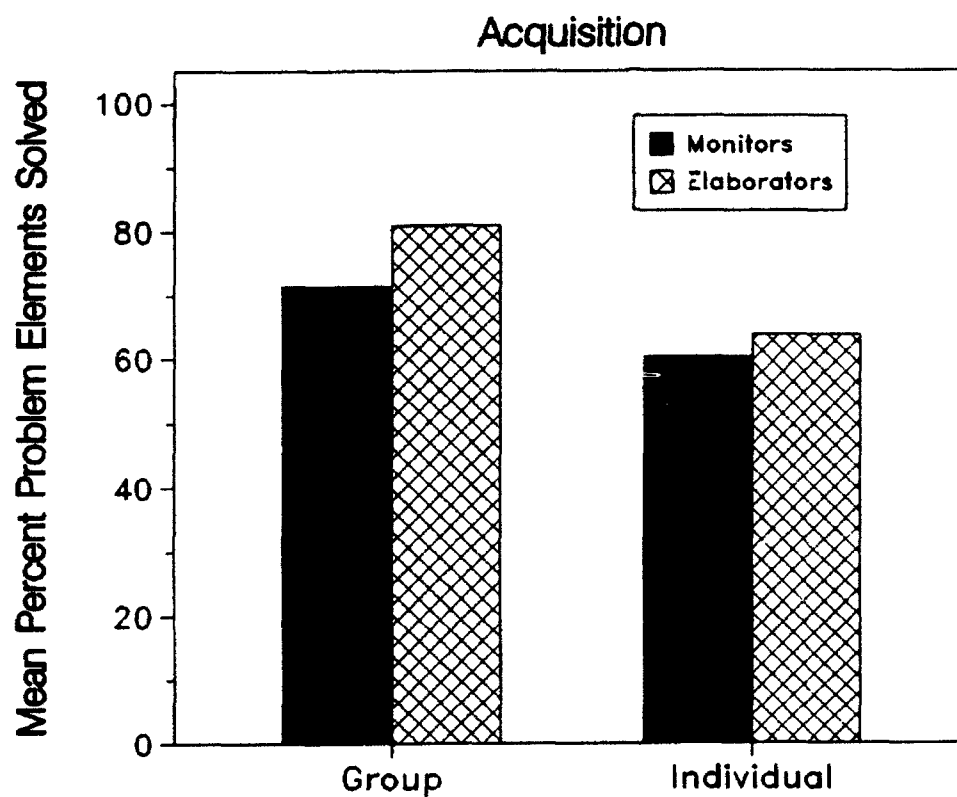


Fig. 15. Primary summary variable for Jasper Metacognitive Activity x Learning Setting conditions.

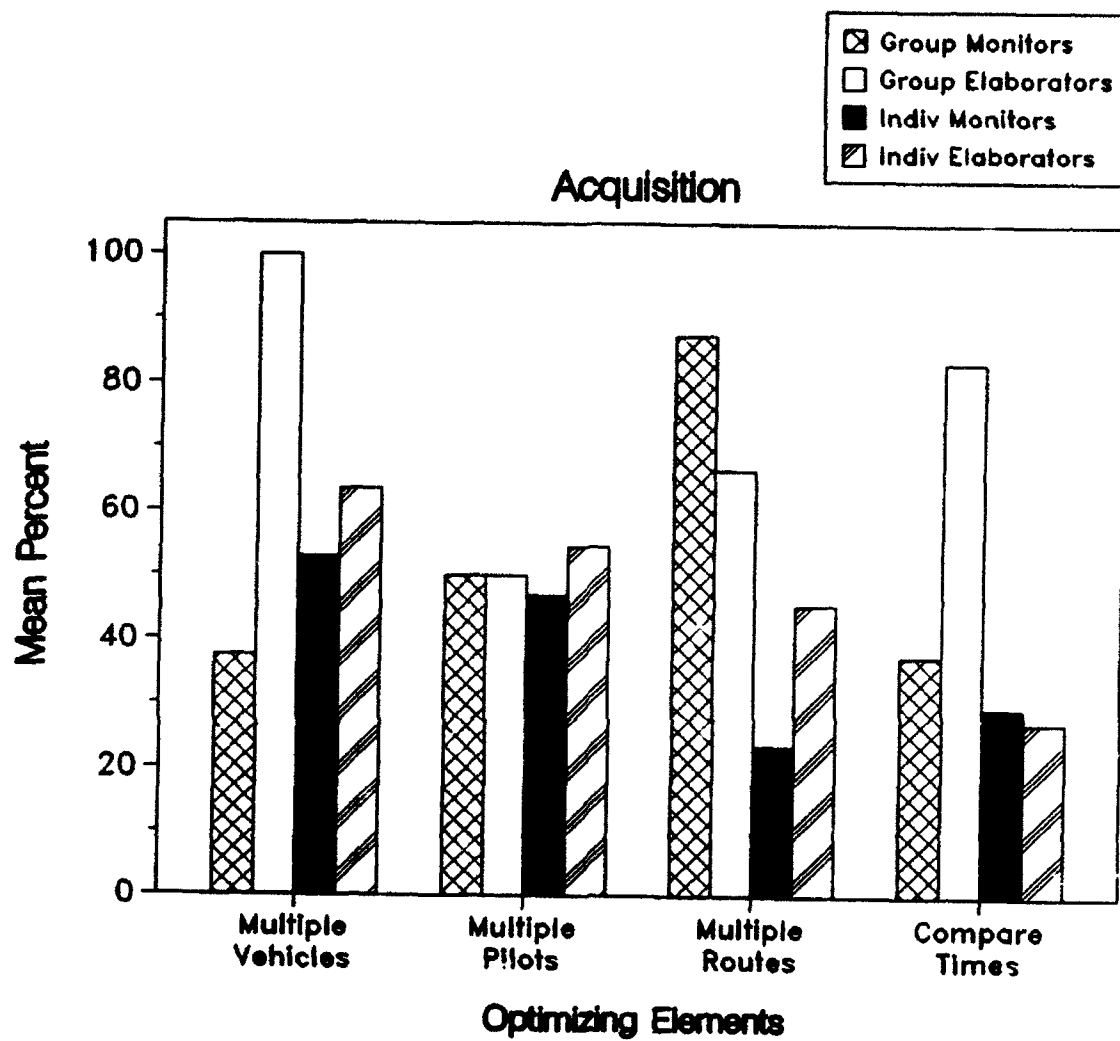


Fig. 16. Inclusion of Jasper optimizing elements for Metacognitive Activity x Learning Setting conditions.

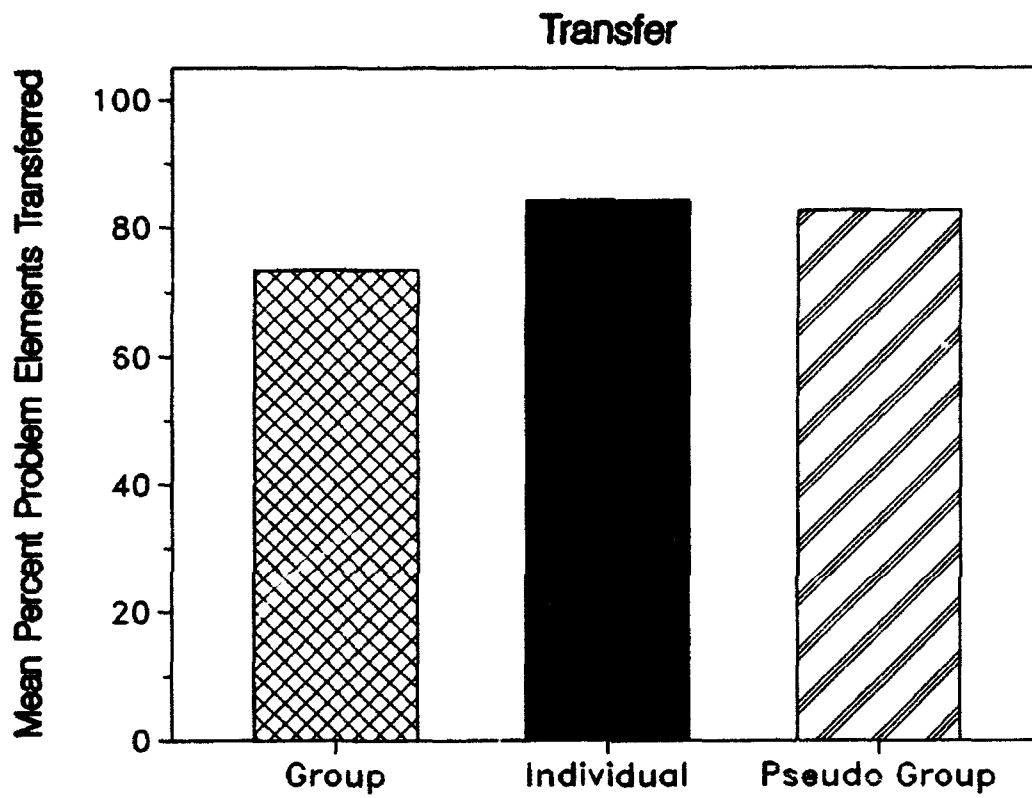


Fig. 17. Primary summary variable for Repsaj Learning Setting conditions.

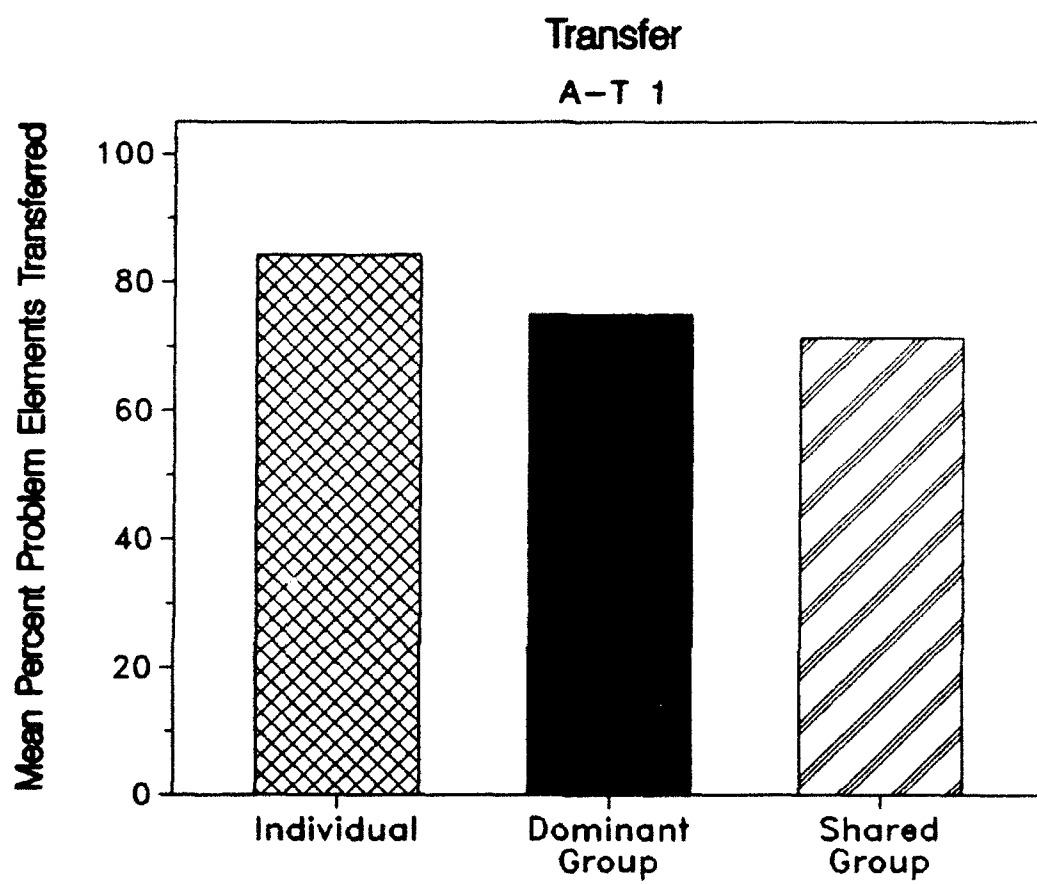


Fig. 18. Primary summary variable for Repsaj Collective Induction conditions.

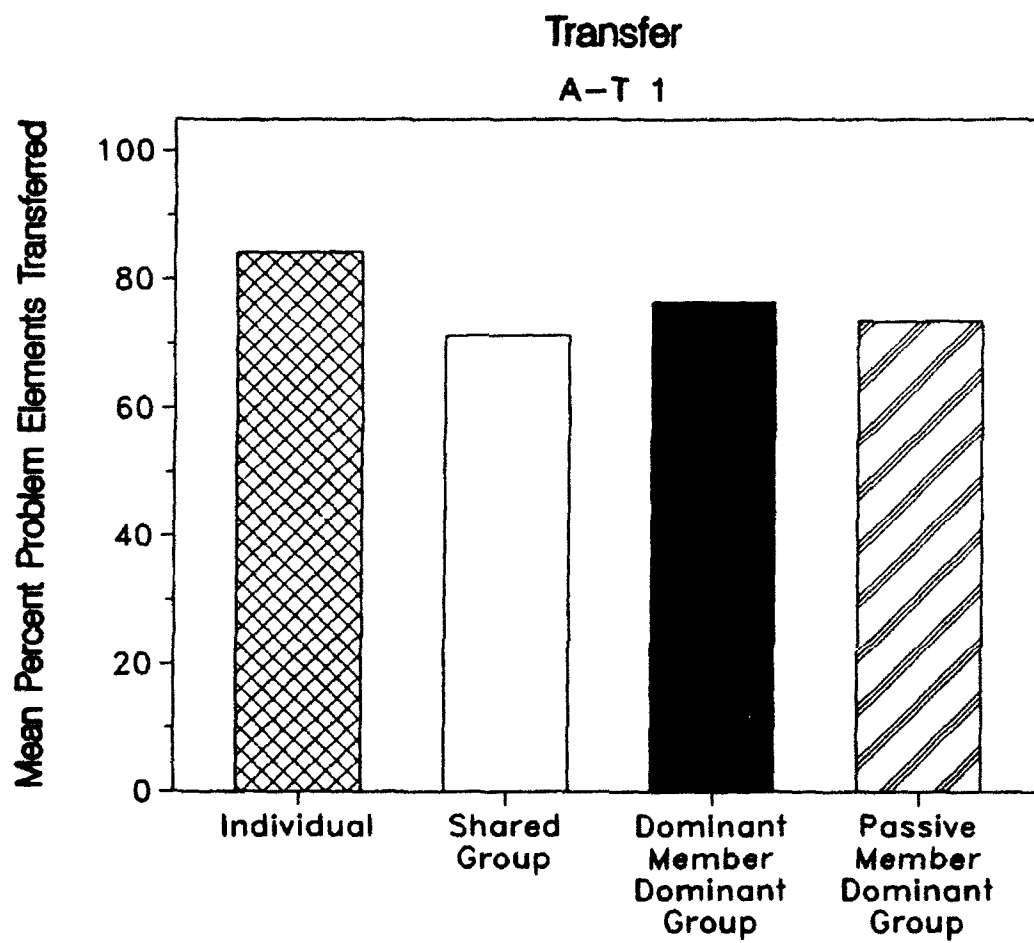


Fig. 19. Primary summary variable for Repsaj Dominant/Passive Member conditions.

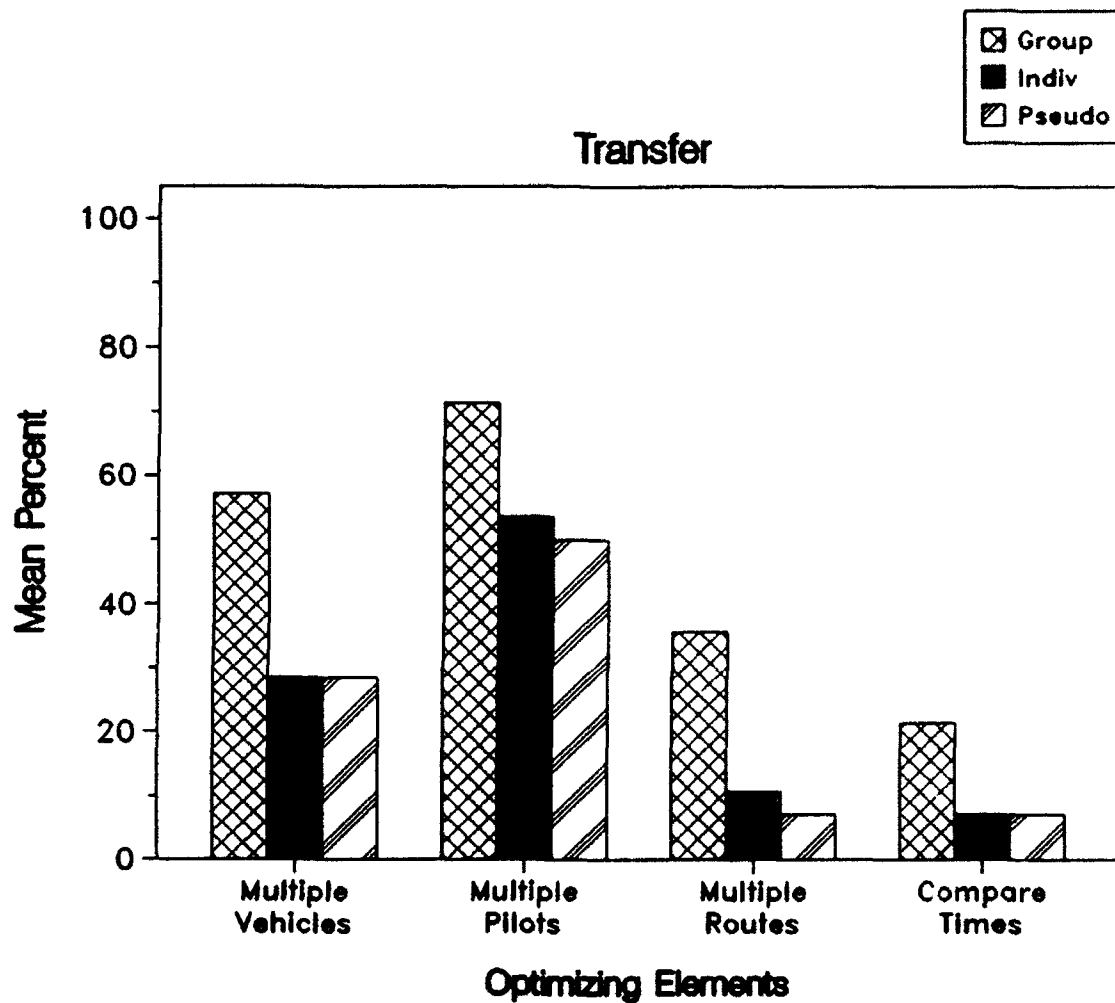


Fig. 20. Inclusion of Repsaj optimizing elements for Learning Setting conditions.

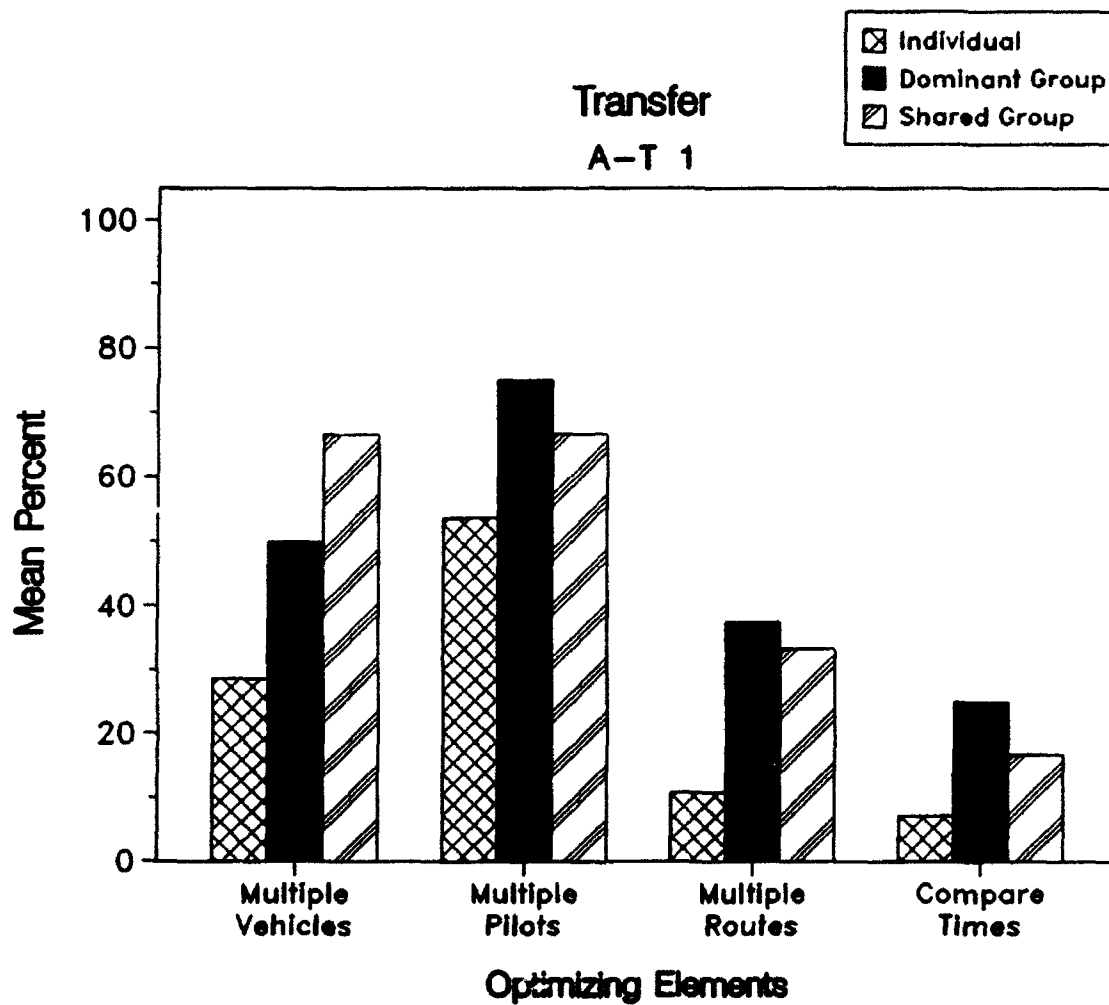


Fig. 21. Inclusion of Repsaj optimizing elements for Collective Induction conditions.

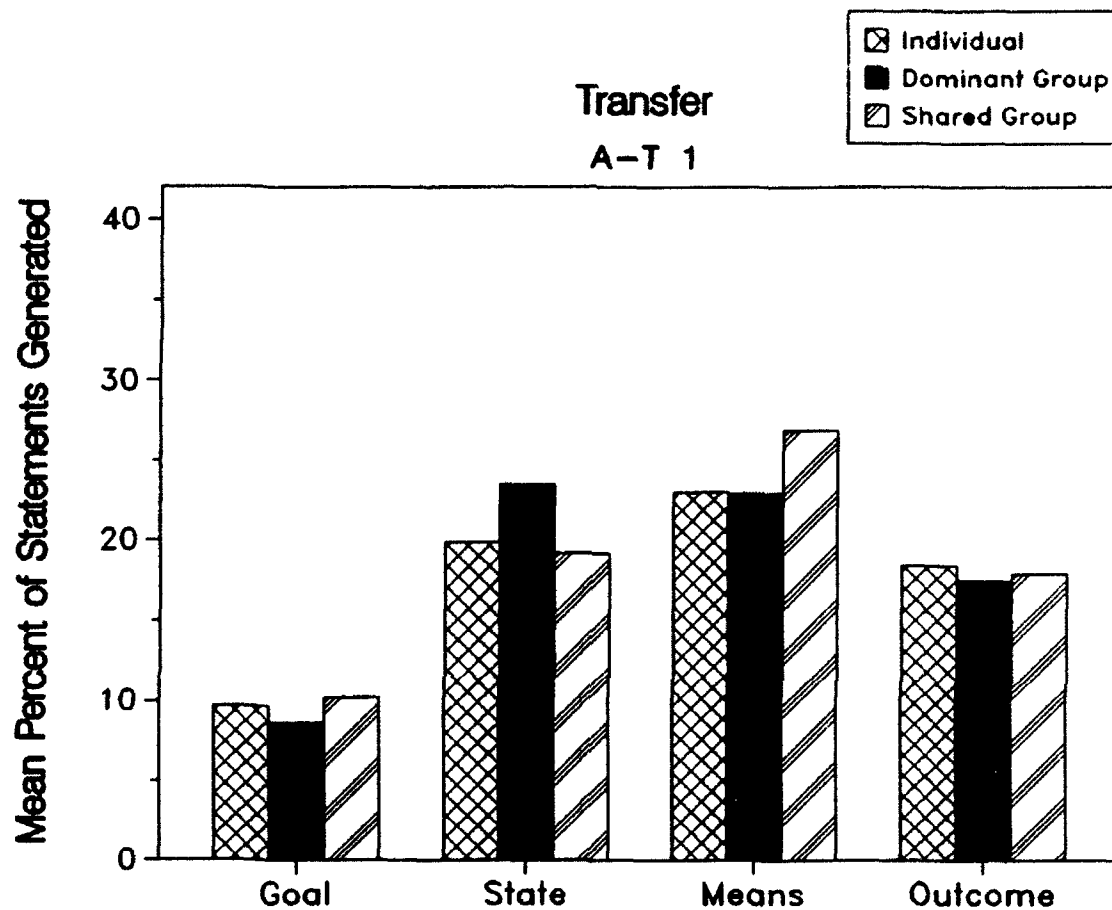


Fig. 22. Learning Setting analysis of goal, state, mean, and outcome statements for Repsaj.

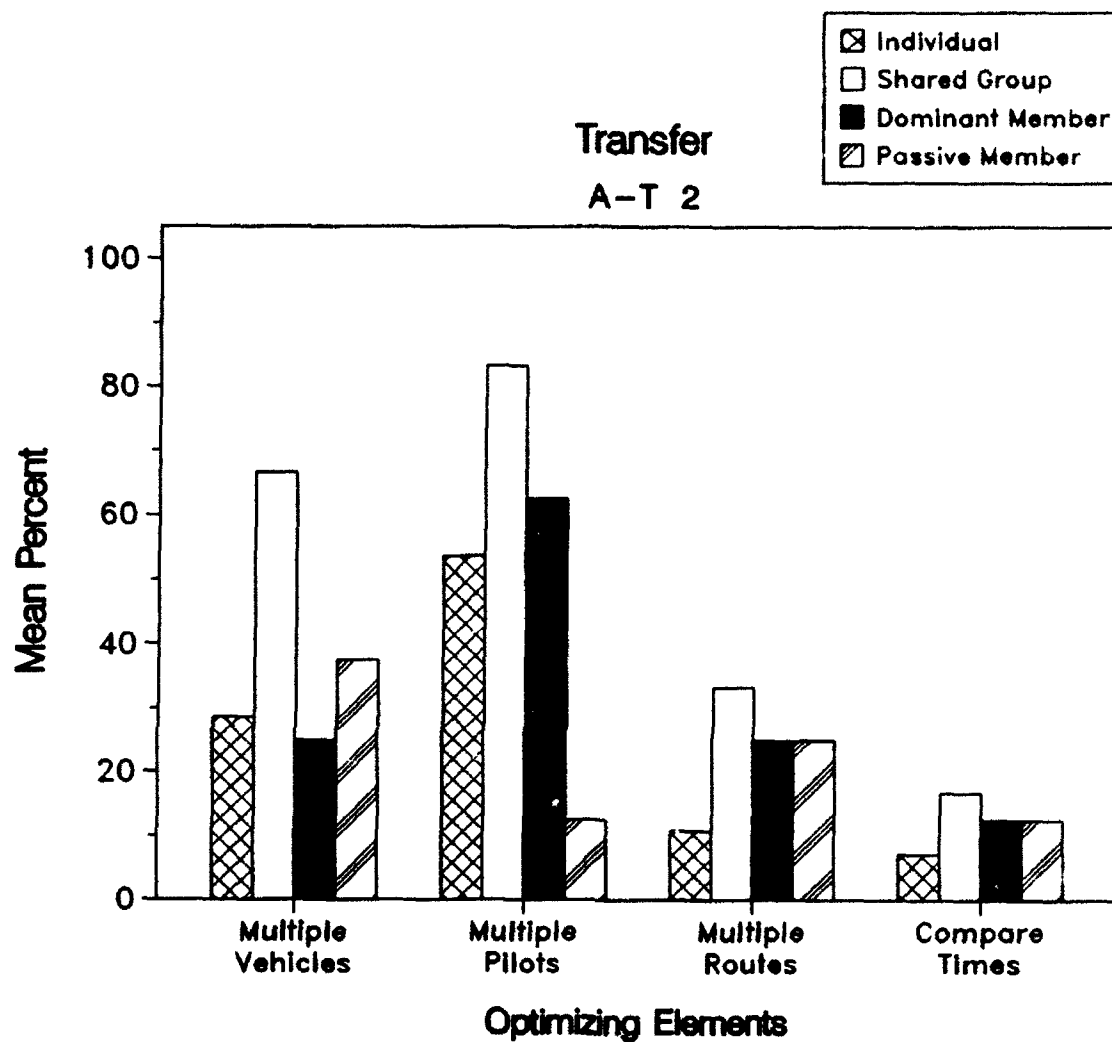


Fig. 23. Inclusion of Repsaj optimizing elements for dominant/passive member conditions (based on cognitive contributions criterion).

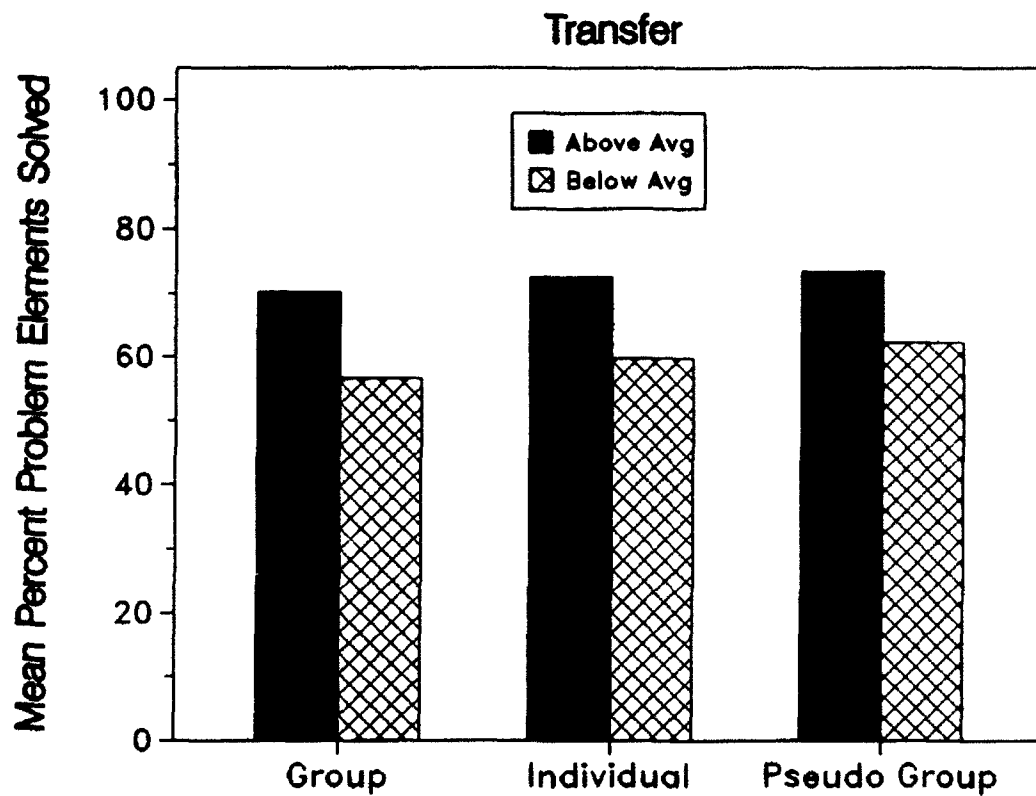


Fig. 24. Percentage of Repsaj problem elements solved for Quality of Solution x Learning Setting conditions.

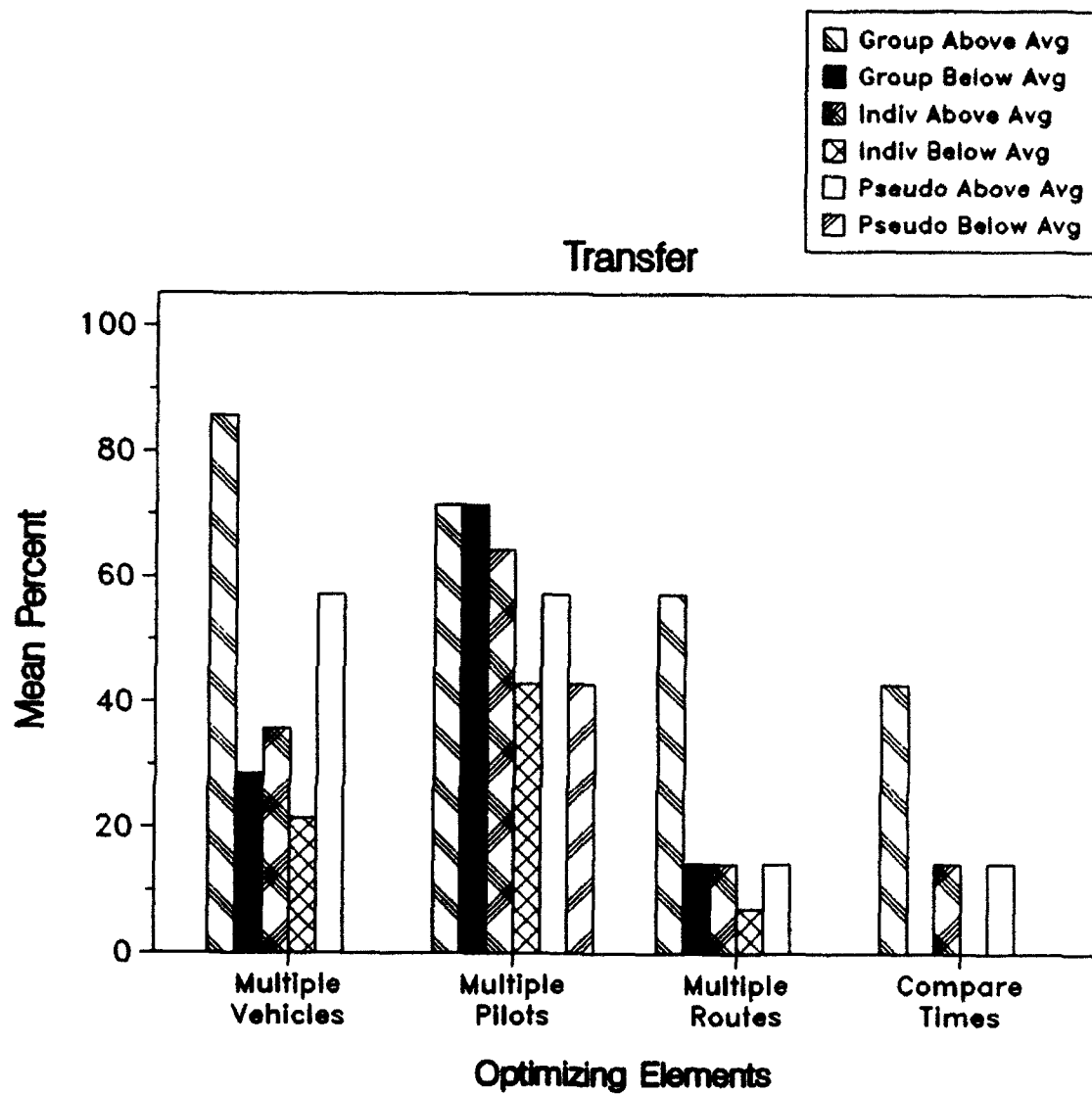


Fig. 25. Inclusion of Repsaj optimizing elements for Quality of Solution x Learning Setting conditions.

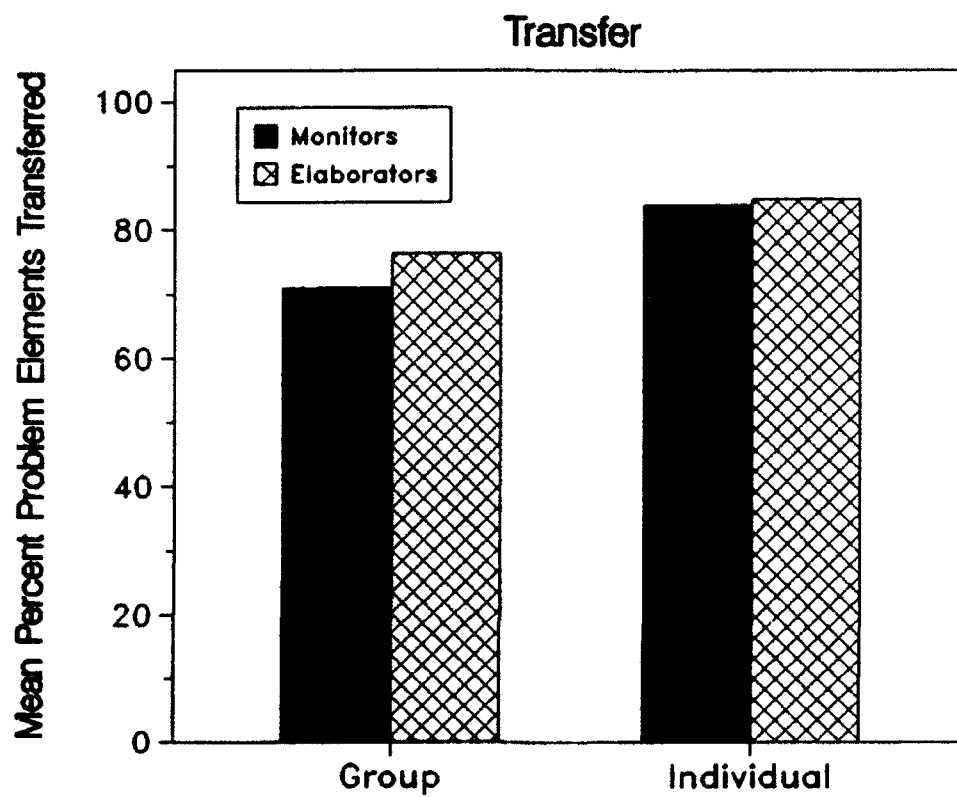


Fig. 26. Primary summary variable for Repsaj Metacognitive Activity x Learning Setting conditions.

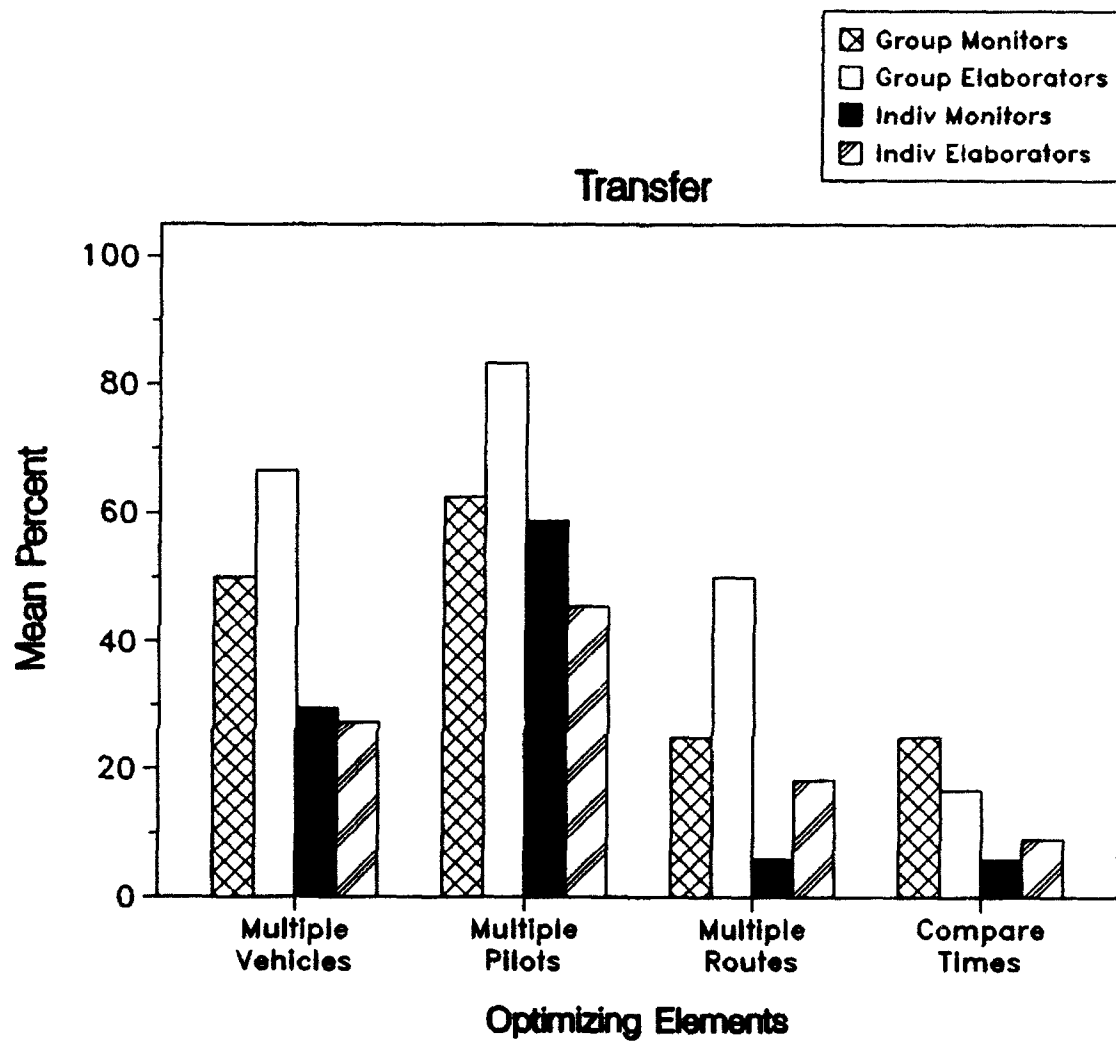


Fig. 27. Inclusion of Repsaj optimizing elements for Metacognitive Activity x Learning Setting conditions.

BIBLIOGRAPHY

- Bereiter, C., & Scardamalia, M. (1989). Intentional learning as a goal of instruction. In L. B. Resnick (Ed.), Knowing, learning, and instruction: Essays in honor of Roger Glaser. Hillsdale, NJ: Erlbaum.
- Bransford, J. D., Sherwood, R. D., Hasselbring, T. S., Kinzer, C. K. & Williams, S. M. (1988). Anchored instruction: Why we need it and how technology can help. In D. Nix & R. Spiro (Eds.), Cognition, education, and multi-media: Exploring ideals in high technology. Hillsdale, N.J.
- Bransford, J. D., Sherwood, R. D., Vye, N. J., & Rieser, J. (1986). Teaching thinking and problem solving. American Psychologist, 41 (10), 1078-1089.
- Brown, A. L. & Campione, J. C. (1991). Communities of learning and thinking, or A context by any other name. Technical Report, School of Education, University of California, Berkeley.
- Brown, J. S., Collins, A., & Duguid, P. (1989). Situated cognition and the culture of learning. Educational Researcher, Jan-Feb, 32-42.
- Clancey, W. L. & Roschelle, J. (in press). Situated cognition: How representations are created and given meaning. to appear in Educational Researcher.
- Cognition and Technology Group at Vanderbilt. (1992). The Jasper experiment: An exploration of issues in learning and instructional design. In M. Hannafin & S. Hooper (Eds.), Educational Technology Research and Development, 40(1), 65-80.
- Cognition and Technology Group at Vanderbilt (in preparation). The Jasper series: Theoretical foundations and data on problem solving and transfer.
- Collins, A., Brown, J. S., Newman, S. E. (1989). Cognitive apprenticeship: Teaching the crafts of reading, writing, and mathematics. In J. Larkin (Ed.), Knowing, Learning, and Instruction: Essays in honor of Roger Glaser. Hillsdale, NJ: Lawrence Erlbaum Associates
- Dansereau, D. F. (1988). Cooperative learning strategies. In C. L. Weinstein, E. T. Goetz, & P. A. Alexander (Eds.) Learning and study strategies: issues in assessment, instruction, and evaluation. San Diego, CA: Academic Press.
- Edwards, D. & Middleton, D. (1986). Joint remembering: Constructing an account of shared experience through conversational discourse. Discourse Processes, 2, 423-459.

- Fletcher, B. C. (1985). Group and individual learning of junior school children on a microcomputer-based task: social or cognitive facilitation. Educational Review, 37 (3), 251-261.
- Gabbert, E., Johnson, D. W., & Johnson, R. T. (1986). Group-to-individual transfer, process gain, and the acquisition of cognitive reasoning strategies in cooperative learning groups. Journal of Psychology, 120 (3), 265-278.
- Gentner, D. (1983). Structure mapping: A theoretical framework for analogy. Cognitive Science, 7, 155-170.
- Gick, M., & Holyoak, K. J. (1980). Analogical problem solving. Cognitive Psychology, 12, 306-355.
- Gick, M. & Holyoak, K. J. (1983). Schema induction and analogical transfer. Cognitive Psychology, 15, 1-38.
- Gibson, J. J. (1979/1986). The ecological approach to visual perception. Hillsdale, NJ: Erlbaum. (Original work published 1979).
- Goldman, S. R., Vye, N. J., Williams, S., Rewey, K., & Pellegrino, J. W. (1991). Problem space analysis of the Jasper problems and students' attempts to solve them. Presented at the poster symposium of the American Educational Research Association Meetings, Chicago, IL.
- Greeno, J. G., Smith, D. R., & Moore, J. L. (in press). Transfer of situated learning. To appear in D. Detterman & R. Stenberg (Eds.), Transfer on trial.
- Hythecker, V. I., Dansereau, D. F. & Rocklin, T. R. (1988). An analysis of the processes influencing the structured dyadic learning environment. Educational Psychologist, 23 (1), 23-37.
- Johnson, D. W. & Johnson, R. T. (1985). The internal dynamics of cooperative learning groups. In R. E. Slavin, S. Sharon, S. Kagan, R. H. Lazarowitz, C. Webb, & R. Schmuck (Eds.), Learning to cooperate, cooperating to learn. New York: Plenum.
- Johnson, D. W., Johnson, R. T. & Maruyama, G. (1983). Interdependence and interpersonal attraction among heterogeneous and homogeneous individuals: a theoretical formulation and a meta-analysis of the research. Review of Educational Research, 53, 5-54.
- Johnson, R. T., Johnson, D. W. & Stanne, M. B. (1986). Comparison of computer-assisted cooperative, competitive, and individualistic learning. American Educational Research Journal, 23 (3), 382-392.
- Johnson, D. W., Maruyama, G., Johnson, R. T., Nelson, D., & Skon, L. (1981). The effects of cooperative, competitive, and individualistic goal structures on achievement: A meta-analysis. Psychological Bulletin, 89, 47-62.

- Johnson, P. E., Moen, J. B., & Thompson, W. B. (1988). Garden path errors in diagnostic reasoning. In L. Blic & M. J. Coombs (Eds.), Expert Systems Applications. Berlin, Germany: Springer-Verlag.
- Kagan, S. (1985). Dimensions of cooperative classroom studies. In R. E. Slavin, S. Sharon, S. Kagan, R. H. Lazarowitz, C. Webb, & R. Schmuck (Eds.), Learning to cooperate, cooperating to learn. New York: Plenum.
- Kamouri, A. L., Kamouri, J., & Smith, K. H. (1986). Training by exploration: Facilitating the transfer of procedural knowledge through analogical reasoning. International Journal of Man-Machine Studies, 24, 171-192.
- Klein, G. A. (1989) Recognition-primed Decisions. In W. R. Rouse, (Ed.), Advances in Man-Machine Research, 5, 47-92. Greenwich, CT: JAI Press, Inc.
- Kugler, P. N., Shaw, R. E., Vicente, K. J., & Kinsella-Shaw, J. (1991). The role of attractors in the self-organization of intentional systems. In R. R. Hoffman & D. S. Palermo (Eds.), Cognition and the symbolic processes. Hillsdale, NJ: Erlbaum.
- Lambiotte, J. G., Dansereau, D. F., O'Donnell, A. M., Young, M. D., Skaggs, L. P. & Hall, R. H. (1988). Effects of cooperative script manipulations on initial learning and transfer. Cognition and Instruction, 5(2), 103-121.
- Larson, C. O., Dansereau, D. F., O'Donnell, A. M., Hythecker, V. I., Lambiotte, J. G., & Rocklin, T. R. (1985). Verbal ability and cooperative learning: Transfer of effects. Journal of Reading Behavior, 16, 289-295.
- Laughlin, P. R. (1989). A theory of collective induction: Final report. Office of Naval Research, Arlington, VA.
- Lave, J. (1989). Cognition in practice: Mind, mathematics, and culture in everyday life. Cambridge, UK: Cambridge University Press.
- Marquart, D. I. (1955). Group problem solving. The Journal of Social Psychology, 41, 103-113.
- McDonald, B. A., Larson, C. O., Dansereau, D. F., & Spurlin, J. E. (1985). Cooperative dyads impact on text learning and transfer. Contemporary Educational Psychology 10, 369-377.
- McGrath, J. E. (1984). Groups: interaction and performance. Englewood Cliffs, NJ: Prentice-Hall.
- McGrath, J. E. (1990). Time matters in groups. In J. Galegher, R. E. Kraut, & C. Egido (Eds.), Intellectual teamwork: The social and technological foundations of cooperative work. Hillsdale, NJ: Erlbaum.
- Meacham, J.A. & Emont, N. C. (1989). Interpersonal bias in everyday problem solving. In J.D. Sinnott (Ed.), Everyday problem solving. New York: Praeger.

- Meeks, L. L. (1987). Developing metacognition in composition with peer response groups. In M. Heiman & J. Slomianko (Eds.), Thinking skills instruction: Concepts and techniques. National Education Association.
- O'Donnell, A. M., Dansereau, D. F., Hythecker, V. I., Hall, R. H., Skaggs, L. P., Lambiotte, J. G., & Young, M. D. (1988). Cooperative procedural learning: Effects of prompting and pre-versus distributed planning activities. Journal of Education Psychology, 80(2), 167-171.
- Palincsar, A. S., & Brown, A. L. (1984). Reciprocal teaching of comprehension-fostering and comprehension-monitoring activities. Cognition and Instruction, 1, 117-175.
- Pea, R. D. (1988). Distributed intelligence in learning and reasoning processes. Paper presented at the meeting of the Cognitive Science Society. Montreal, Canada.
- Rasmussen, J. & Pejtersen, A. M. (in progress). Virtual ecology of work. To appear in J. M. Flach, P. A. Hancock, Caird, J., K. J. Vicente (Eds.), The ecology of human-machine systems. Hillsdale, NJ: Erlbaum.
- Rogoff, B. (1990). Apprenticeship in thinking. New York: Oxford University Press.
- Rogoff, B., & Lave, J. (Eds.). (1984). Everyday cognition: Its development in social context. Cambridge, MA: Harvard University Press.
- Ross, B. H. (1987). This is like that: The use of earlier problems and the separation of similarity effects. Journal of Experimental Psychology: Learning, Memory, and Cognition, 15, 456-468.
- Sanderson, P. (1990). Verbal protocol analysis in three experimental domains using SHAPA. In Proceedings of the Human Factors Society 34th Annual Meeting, Orlando, Florida, October 8-12.
- Shaw, R., Turvey, M. T., & Mace, W. (1982). Ecological psychology: The consequences of a commitment to realism. In W. B. Weimer & D. S. Palermo (Eds.), Cognition and the symbolic processes, (vol. 2). Hillsdale, NJ: Erlbaum.
- Siegler R. S. & Jenkins, E. (1989). How children discover new strategies. Hillsdale, NJ: Erlbaum.
- Sinnott, J. D. (1989). A model for solution of ill-structured problems: Implications for everyday and abstract problem solving. In J.D. Sinnott (Ed.), Everyday problem solving: Theory and Applications. New York: Praeger.
- Slavin, R. E. (1980). Using student team learning. Baltimore: John Hopkins Team Learning Project.
- Slavin, R. E. (1983). When does cooperative learning increase student achievement? Psychological Bulletin, 94, 429-445.

- Slavin, R. E. (1987). Developmental and motivational perspectives on cooperative learning: A reconciliation. Child Development, 58, 1161-1167.
- Smith, K., Johnson, D. W., & Johnson, R. T. (1981). The use of cooperative learning groups in engineering education. In L. P. Grayson & J. M. Biedenbach (Eds.), Proceedings: Tenth annual frontiers in education conference, Washington, DC: American Society for Engineering Education.
- Spear, K. (1988). Sharing writing. Portsmouth, NH: Boynton/Cook Publ.
- Spurlin, J. E., Dansereau, D. F., Larson, C. O., & Brooks, L. W. (1984). Cooperative learning strategies in processing descriptive text: Effects of role and activity level of the learner. Cognition and Instruction, 1, 451-463.
- Way, W. (1985). The role of the future homemakers of america student organization in facilitating the development of critical thinking skills. Paper presented at the Meeting of the American Vocational Association, Atlanta, GA.
- Webb, C. (1985). Cooperative learning in mathematics and science. In R. E. Slavin, S. Sharon, S. Kagan, R. H. Lazarowitz, C. Webb, & R. Schmuck (Eds.), Learning to cooperate, cooperating to learn. New York: Plenum. Adams, Kasserman, Yearwood, Perfetto, Bransford, & Franks 1988
- Wegner, D. M. (1987). Transactive memory: A contemporary analysis of group mind. In B. Mullen & G. R. Goethals (Eds.), Theories of group behavior. New York: Springer-Verlag.
- Young, M. F., & McNeese, M. D. (in press). A Situated cognition approach to problem solving. To appear in J. M. Flach, P. A. Hancock, J. Caird, K. J. Vicente (Eds.), The ecology of human-machine systems. Hillsdale, NJ: Erlbaum.